ELECTRICAL ENGINEERING PROBLEMS

PART I

DIRECT CURRENT CIRCUITS AND APPARATUS

PART II

ALTERNATING CURRENT CIRCUITS AND APPARATUS

BY

F. C. CALDWELL, A.B., M.E.

Professor of Electrical Engineering at the Ohio State University,
Fellow American Institute of Electrical Engineers

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PREFACE

This little book of problems is offered as a system of exercises, suitable for use with any of the available textbooks or with a lecture course. Most of the problems have been used in the classes of the author. A novel feature is the stating of the time needed to perform the actual solving of each problem. This should prove useful not only to the instructor in the assignment of problems, but also to the student as a measure of his own speed. In most of the problems the time given is that which was actually used by an undergraduate student. It will, however, probably be found necessary to allow more time to the average class than is here indicated.

Sheets giving the answers to the problems will be provided in such quantities as may be needed, but only to instructors.

F. C. C.

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CONTENTS

PART I

DIRECT-CURRENT CIRCUITS AND APPARATUS

PART II

ALTERNATING-CURRENT CIRCUITS AND APPARATUS

ABBREVIATIONS

B, gausses. C, conductors. c.p., candle-power. e.m.f., electro-motive-force. H, magneto-motive-force per centimeter length. h.p., horse-power. i, current. kw., kilowatt. kv-a., kilovolt-ampere. l, length. N, turns. R, resistance. r.p.m., revolutions per minute.

As subscripts. a, armature; g, gap; m, magnet; s, shunt, f, series field.

PART I

DIRECT CURRENT CIRCUITS AND APPARATUS

ELECTRICAL ENGINEERING PROBLEMS

PART I

CHAPTER I

ELECTROMOTIVE FORCE, CURRENT, CONDUCTANCE AND RESISTANCE

1. Given three 110-volt tungsten lamps with resistances of 50, 120 and 200 ohms in series, with 330 volts applied across the outside, what will be the difference of potential around each lamp? (*3 min.*)

2. Given circuits of 4 and 6 ohms in parallel, and in series with these a circuit of 7.6 ohms. What current will be sent through this combination of circuits by 120 volts? If each of the resistances be halved, what will the current be? (*2 min.*)

3. Given two circuits of 5 and 7 ohms in parallel between two points A and B, and in series with these, 10 ohms between B and another point C. If 310 volts be applied between A and C, required the volts between A and B, and between B and C and also the current flowing. (*4 min.*)

4. Five 625-ohm, 20-candle-power and four 392-ohm, 32-candle-power, 125-volt tungsten lamps are all in parallel. The resistance of the circuit connecting them to the generator is 2 ohms. Find the conductance of each lamp and of the whole group, the current taken by each lamp and the voltage required at the generator to give the lamps their proper current. (*8 min.*)

5. Given three circuits of 5, 3 and $1\frac{3}{11}$ ohms respectively in series, and in series with these, two parallel circuits of 5 and 6 ohms. With 360 volts applied to the outside terminals, what will be the pressure on the 3-ohm circuit and what current will flow? If this circuit be changed from 3 to 15 ohms, in what ratio will the drop around the 5-ohm circuit be changed? (*3 min.*)

6. The voltage between the terminals of a 6-foot piece of wire is 50 and its resistance is 100; for the calibration of a volt-

meter $12\frac{1}{2}$ volts are wanted; how many ohms of the resistance of the wire and what length must be included between the terminals of the voltmeter? (The voltmeter is supposed to have an infinite resistance.) (*1 min.*)

7. Two resistances of 50 and 100 ohms are connected in parallel between two points A and B, between which the e.m.f. is 100 volts; what current will flow in each circuit? If the 100-ohm circuit be reduced to 0.05 ohm, what current will flow in each? (*2 min.*)

8. Circuits P, Q and R are in parallel, as are also circuits S and T; these two groups are in series. If 270 volts are applied to the outside terminals of the combination, find the conductance and resistance of each group and the current in each circuit, the resistances of the circuits being 3, 5, $7\frac{1}{2}$, 20 and 30 ohms respectively. (*7 min.*)

9. A resistance of 42 ohms between A and H is tapped at six equidistant points, B, C, D, E, F and G; four switches are placed between A, C, E and G, and one bus bar, and four between B, D, F and H, and the other bus bar. Find the conductance and resistance between the bus bars with each of the following six groups of switches closed — A, B and G; A, C and H; A, D and G; A, B, C and H; A, B, C, G and H; all closed. (*8 min.*)

10. Four points A, B, C and D are at the successive corners of a square and resistances are connected between them as follows: AB, 2 ohms; BC, 6 ohms; CD, 12 ohms; BD, 100 ohms. What resistance must be placed between D and A in order that no current shall flow through the circuit BD when 10 volts is applied between A and C? What if 100 volts be applied? (*2 min.*)

11. The field of a 15-kw. shunt motor has a resistance of 25 ohms; what current will flow when it is connected in on a constant-potential 125-volt circuit? If the armature, the resistance of which is 0.04 ohm, was connected in parallel (not running), what current would flow through it? What would then be the current through the field? What would happen to the armature? If a 5-ohm rheostat were included in the armature circuit, what would be the total current taken by the motor? (*4 min.*)

12. A 70-cell storage battery, designed to give 100 amperes for 8 hours, has a resistance of 0.0005 ohm per cell. When the charging of the battery is nearing completion, the cells have an electromotive force of 2.5 volts each. If a 220-volt generator is being used for charging at 100 amperes, what voltage must be

used up in resistance, and how many ohms will be needed? (*3 min.*)

13. The shunt-field resistance of a 10-kw., 120-volt generator is to be measured. A rheostat is in series with it on the 120-volt circuit. The current is 2 amperes and the drop around the field is 106 volts. What is the resistance of the field, of the rheostat and of the combination? (*2 min.*)

14. In measuring a certain railway current a "shunt" having a resistance of 0.00025 ohms is connected in the circuit, and a millivoltmeter attached to its terminals reads 0.05 volts. What is the value of the current? Why should the resistance in this shunt be so low? (*2 min.*)

CHAPTER II

WIRES, WIRE TABLES, RESISTIVITY AND TEMPERATURE COEFFICIENT

Note. — Unless otherwise stated the resistivity of copper at atmospheric temperature may be taken as 11 (based on the circular mil-foot).

Note also that in the American, or Brown & Sharp wire gauge the diameters of the wires from No. 6 to No. 12 are approximately the reciprocals of the numbers expressed in inches; thus No. 10 is $\frac{1}{10}$ inch or 100 mils diameter (actual 102). Also that the diameter doubles for every 6 numbers and the area for every 3 numbers, and the area increases 10 times for 10 numbers. Use the B. & S. wire table on page 103.

1. By referring to the diameters of the sizes from 6 to 12, obtained without consulting the tables, determine the approximate diameter in mils and the area in circular mils of the following wires: Nos. 35, 23, 5, 1. Determine also the per cent errors in area that would be made in using these approximations. (See wire table for exact sizes.) (*15 min.*)

2. The area of a No. 10 wire being 10,400, what will be the approximate area of a No. 4 wire? Of a No. 13? Of a No. 20? (*2 min.*)

3. If one dimension of a rectangular wire is to be twice the other, what must they be in inches to replace a No. 6 wire? What will be the area in sq. mm.? (*4 min.*)

4. How many square mils and how many circular mils in a wire $\frac{1}{4}$ inch by $\frac{3}{16}$ inch? Also if this wire is rounded at the corners with a radius of 20 mils, what will be its area in circular mils? (*4 min.*)

5. Without consulting the tables determine what B. & S. wires will have to be used in circuits requiring the following areas of copper: 40,000, 3600 and 100 circular mils. Also for the following diameters in mils: 7.5, 19, 62, 135 and 240. (*6 min.*)

6. Given a copper wire 300 feet long and 6529 circular mils cross-section, No. 12 B. & S., find the volts to give 25 amperes. Also if the length be made 600 feet. (*2 min.*)

7. 2000 feet of No. 10 wire, 102 mils in diameter, has a resistance of 2 ohms at 20° C. What is the resistivity of the material? What might the material be? (*1 min.*)

8. 3500 feet of No. 25 wire of a certain material used for conductors has a resistance at 20° C. of 175 ohms. Its area is 320 circular mils. What is the resistivity and what is the material? (*2 min.*)

9. Given the temperature coefficient of copper as 0.004, and the resistance of a circular mil-foot at 25 degrees as 10.55; required the resistance of a No. 18 wire 150 feet long at 55° C. (*2 min.*)

10. At the working temperature of 70° C., the field of a shunt dynamo has a resistance of 100 ohms; how many feet of No. 14 B. & S. German silver wire, whose resistivity is 290, must be inserted in series to keep the field current the same, when the machine is started at a room temperature of 10° C.? (*5 min.*)

11. Required the e.m.f. necessary to send 25 amperes through one mile of No. 10 copper wire. If a generator supplied 500 volts at one end of this circuit, what e.m.f. would be available to run a motor at the other? Would this be an economical transmission? (*4 min.*)

12. A lighting plant is, during the day, supplying two 250-ohm incandescent lamps connected in series, at a distance of 500 feet from the station, with current at 250 volts, the conductors being one inch in diameter. At evening, 500 additional pairs of two lamps (in series) are placed in parallel with the pair already burning. Required the current flowing through the two lamps during the day, the total amount of the night load in amperes and the change in the current through the two original lamps; what would this change be if the resistance of the feeding wires were zero? (*6 min.*)

13. A voltmeter has a resistance with the leads of one ohm, and is to be used at a distance of 25 feet, and connected with a copper wire having a temperature coefficient of 0.004 per degree C. Required the area and size of wire necessary in order that an increase of 8 degrees from 24° C. may not cause an error of over $\frac{1}{2}$ per cent. Take resistivity for 24 degrees as 10.5. Note that the voltmeter is calibrated with the leads in series, and also that the readings are independent of the temperature of the instrument. (*5 min.*)

CHAPTER III

POWER AND WORK

1. 50 amperes at 110 volts give how many horse-power? Required the current at 500 volts to give the same horse-power; also at 1000 volts. (*2 min.*)

2. At 8 cents per kilowatt-hour how much will it cost, per week of 60 hours, to run a motor having an average load of 4 horse-power and an average efficiency of 80%? (*3 min.*)

3. A 20-candle-power tungsten incandescent lamp takes 1.3 watts per candle-power; a common price for this purpose is 10 cents per kw.-hour; at this price, what will it cost to run 8 lamps for three hours? (*2 min.*)

4. What must be the horse-power delivered by an engine to run by belt a generator feeding 500 $\frac{1}{2}$-ampere lamps at 110 volts? Four volts are lost in the line, the efficiency of the generator is 90% and the loss in the belt is 1%. (*4 min.*)

5. A motor at 1000 feet from the generator requires 20 amperes at 500 volts. The wire used is a No. 6. Required the e.m.f. at the generator and the per cent of the volts lost; also the power lost and the per cent of the power lost. (*5 min.*)

6. Same as problem 5 but using No. 4 wire. (*5 min.*)

7. What will be the loss in pressure and in watts in transmitting 100 horse-power at 500 volts through a No. 0000 wire, taking the resistance for 30° C. as 0.05086 ohms per 1000 feet, and the distance being one mile? What are the respective per cents of e.m.f. and power lost? (*5 min.*)

8. A 220-volt motor with 80% efficiency gives 8.94 horse-power, is 1000 feet distant from the generator and is wired with a No. 6 wire; how many horse-power are lost in the circuit, and at what voltage must the generator run in order that the motor may have its proper pressure? What per cent of the delivered e.m.f. and power is lost in the transmission? (*6 min.*)

9. A test with a Prony brake shows that a certain motor is giving 132,000 foot-pounds per minute. The input is 7.46 amperes at 500 volts. What is the efficiency? (*2 min.*)

10. For the direct driving of a factory the following list of motors is necessary:

Number	H. P.	Efficiency
1	100	92%
2	30	90
6	20	88
10	5	83
20	2	75

On this circuit the full-load line loss is 5% of the power delivered to the motors.

There are also 100 32-candle-power tungsten incandescent lamps taking 1.25 watts per candle power, and 10 flaming arcs taking 550 watts each. Line loss is neglected on the lighting circuit.

What will be the kilowatt capacity of the direct-connected generator and what horse-power must the engine give if the dynamo efficiency is 94%? *(11 min.)*

CHAPTER IV

MEASUREMENT OF CURRENT AND E.M.F.

1. It is required to measure 5542 amperes by means of a resistance of 5×10^{-6} ohms and a voltmeter; draw a diagram of the connections, and show what would be the reading of the voltmeter and what power would be lost in the shunt. Why not use a 0.001-ohm resistance? (*5 min.*)

2. Five lamps having resistances of 193, 203, 207, 197 and 200 are put in series across a railway circuit, and a 150-volt voltmeter of infinite resistance is connected around the 200-ohm lamp; it reads 97 volts; what is the pressure on the circuit? What would be the reading for this pressure if the resistance of the voltmeter were only 500? How low a resistance in the voltmeter could be left out of the calculation for an accuracy of $\frac{1}{2}$ per cent? (*17 min.*)

3. It is desired to use a 50-millivolt meter as a 200-ampere meter on a 500-volt circuit. What resistance must the shunt have? Same for a 0.2-ampere meter. What will be the voltage on the instrument if the shunt is opened between the millivoltmeter terminals? (*3 min.*)

4. How low could the resistance of the millivoltmeter used in each case of problem 3 be, without introducing an error of more than $\frac{1}{10}$ per cent? (*6 min.*)

5. A 150-volt meter having a resistance of 16,000 ohms is to be used with a multiplier as a 600-volt instrument. What resistance must the multiplier have? (*3 min.*)

6. If the readings on a 150-volt meter can be estimated accurately to 0.2 of a division, what per cent of accuracy can be obtained at 1.5, 15 and 150 volts respectively? (*2 min.*)

CHAPTER V

MAGNETISM AND MAGNETIC CIRCUITS

1. Upon cross-section or coördinate paper construct the magnetization curves from page 105, for cast iron, cast steel, wrought iron and sheet steel. Plot with magnetizing force H for abscissæ, and density B for ordinates. Use the same scale for all the curves and, while taking one that is easily read, choose it so as to occupy with the curves as much of the sheet as practicable. Carry the curves to about H = 200. *(30 min.)*

2. Given a ring of cast iron, 50 cm. in circumference; required the gilberts necessary to give 6500 gausses, and also the turns, if the current is 5 amperes. *(2 min.)*

3. If a cut be made in the ring of the last problem and spread out to $\frac{1}{2}$ cm. gap, what will be the total number of turns necessary for the same density? *(2 min.)*

4. A forged ring has a mean diameter of 45 centimeters, and an area of 30 sq. cm. The flux is 450 kilomaxwells. Required the gilberts and the ampere turns necessary. *(5 min.)*

5. Required the reluctance in œrsteds of the above ring at the density used; also the permeability. *(4 min.)*

6. Required the reluctance in œrsteds of a cast-iron ring of the same dimensions as in problem 5 and having a permeability of 200. What density does this indicate? Compare with the reluctance found in problem 5. *(8 min.)*

7. A horseshoe-shaped magnet for hoisting rails is forged of wrought iron and has a magnetic path 40 cm. long; the oxide on the rail is 0.1 mm. thick (note the two gaps), and the path through the rail is 15 cm. The density in the magnet is 16,000 gausses, and the cross-section of the rail is double that of the magnet. Magnetizing force H for both irons is to be taken as for wrought iron. Required the number of turns necessary in the winding if the exciting current is two amperes. *(4 min.)*

8. A cast-steel magnetic clutch for driving a pulley must pull its armature up when it is 1 mm. away (note the two gaps). Its

magnetic path including the armature is 30 cm. To do this, the density through the air must be 8000 gausses, which will require 11,000 in the magnet and armature. How many turns will be necessary with an exciting current of 3 amperes? What would the density become when the armature was pulled up? (*6 min.*)

9. The magnetic circuit of a dynamo is made up as follows: cast-iron ring, length of path 25 cm., density 6000, two wrought-iron cores each 10 cm. long, with density of 16,000, two gaps 5 mm. long, with mean density of 8000, the path through the laminated armature 15 cm. long with a density of 10,000. Required the ampere-turns necessary for the excitation. (*4 min.*)

10. Given a cast-steel ring, 8 inches inside diameter, 2 inches diameter of iron; B is 15,000 gausses. Required the maxwells, the œrsteds and the exciting current if there are 150 turns. (*8 min.*)

11. Given a cast-iron ring 100 cm. in mean diameter. Required the number of amperes necessary to make B equal to 4000, 6000, 8000 and 10,000 if the winding be of 854 turns. (*6 min.*)

12. In the case of the last example, if the winding has a resistance of 3.76 ohms, what will be the power necessary to produce each density? Note great increase in power with increase in density. (*5 min.*)

13. In order to raise a certain weight the density in a horseshoe-shaped forged hoisting magnet must be 16,000 gausses; the length of the iron circuit is 50 cm. If there are 1428 turns carrying two amperes, how near to the weight must the magnet be brought to lift it. If the current were increased to 7.14 amperes, how many turns would be necessary? (*7 min.*)

14. A dynamo magnetic circuit is made up of the following parts: 27 cm. in the armature with a density 7000; two clearances of 3.4 mm. each, with B equal to 12,000, and a cast-steel field of 53 cm. with a density of 15,000. If the magnetizing current be 10 amperes, how many turns will be necessary? (*4 min.*)

15. A 2-kw. transformer has a magnetic circuit whose section is 7.57×5.22 inches and length 22.3 inches. If there are 800 turns and a maximum density of 5000 is necessary, what will be the maximum magnetizing current? (*4 min.*)

16. The hysteresis loop for a sample of sheet steel is carried to 13,750 gausses. The coördinates are chosen so that one inch represents ten units of magnetizing force and 10,000 gausses. The area of the curve is found to be 0.513 sq. in. What would be

the watts loss if 1000 cubic centimeters of this iron were subjected to 25 cycles per second? (*12 min.*)

Note. — 1 watt-second = 10^7 ergs.

17. Plot the curves of permeability with gausses as abscissæ for sheet steel and for cast iron. Take the data from the tables on page 105 and plot about 15 points on each. (*20 min.*)

18. It is required to design a forged-steel horseshoe to raise 1000 pounds. The length of the iron path in the magnet is 50 cm. and there will be two gaps of 0.1 mm. A density of 16,000 is to be used in the steel, which on account of leakage will be reduced to 15,000 in the gaps. On account of greater cross-section, neglect the reluctance of the armature. Required the diameter of the iron and the gilberts needed. If a current of 2 amperes is to be used for excitation, how many turns will be required? (*9 min.*)

Note. — The magnetic pull is $\dfrac{B^2A}{4\pi \times 981}$ grams or $\dfrac{B^2A}{11.17}$ where the pull is in pounds, the density in kilogausses and the area (total surface) in square centimeters.

19. Two parallel surfaces 9 × 8 and 7 × 5 cm. respectively are 10 cm. (normal to surfaces) apart. Find the permeance of the space between them. (*1 min.*)

20. Required the permeance between two parallel surfaces 13.3 × 21.4 and 9.42 × 21.4 cm. respectively, and 6.31 cm. (normal to surfaces) apart; also the flux if the winding consists of 1270 turns carrying 1.32 amperes. (*3 min.*)

21. Two surfaces 9 × 20 cm. lie in the same plane and have their long edges parallel and 2 cm. apart. Required the permeance of the path between them. If a magnetomotive force, produced by 1000 turns, carrying two amperes, acted between these two surfaces, required the total flux between them. Assume the lines of force to be semicircles. (*3 min.*)

Note. $P = \dfrac{L}{\pi}\log_\epsilon \dfrac{D_2}{D_1} = 0.733\ L\ \log_{10}\dfrac{D_2}{D_1}$, where L = length of parallel edges and D_2 and D_1 = the distances between the outer and inner edges. (Found by integration of elementary leakage path. See Standard Handbook, Sec. 5, § 57.)

22. Two surfaces 7.12 × 22.5 cm. in the same plane, and 1.2 cm. apart with the long sides parallel. Assuming the lines of force to be semicircles; required the permeance. (*5 min.*)

23. The flux in the armature of a bipolar, 110-volt, 6-kw. generator is 3×10^6, while that in the field is 3.9×10^6. Required the leakage coefficient. (½ *min.*)

24. In a bipolar, 110-volt, 4 kilowatt generator, the armature density is 14,000 and the total flux 2.8×10^6. The leakage coefficient is 1.25; required the area of the field magnet, if a density of 12,000 be used. (*3 min.*)

25. In a 50-kw., 110-volt, 4-pole generator the armature density is 14,000, and the double cross-sectional area of the ring, 550 sq. cm. In the field-magnet ring the density is 12,000 and the double area is 820 sq. cm.; required the leakage coefficient. (*2 min.*)

26. Given the leakage coefficient 1.32 and the armature flux 10.63 megamaxwells. The yoke of the dynamo is to be of cast iron. Required the dimensions of its cross-section in inches for B equal to 7200 if its length is to be twice its breadth. (*4 min.*)

CHAPTER VI

MAGNET WINDINGS AND MAGNETS

1. Given the following data: resistivity 12; ampere-turns 4000; mean length of turn 18 inches; e.m.f. 50 volts. What area of wire should be used and what B. & S. number will answer? (*2 min.*)

Note. — The area is obtained from the formula for drop in terms of number and mean length of turns, resistivity, current and area.

2. A magnet requiring 20,000 ampere-turns is used on a 500-volt circuit; the mean length of a turn is 2 feet; the resistivity is 12; the circular mils per ampere 1000. Required the area and the B. & S. number of the wire and the number of turns, using the B. & S. size, and remembering that the larger wire will mean more ampere-turns. (*5 min.*)

3. Required the diameter in centimeters of a horseshoe magnet to raise 4000 pounds with B equal to 16,000. (*4 min.*)

4. Given a coil of wire $5\frac{1}{2}$ inches inside and $6\frac{1}{2}$ outside diameter. 13,400 ampere-turns are necessary; resistivity is 12.5; e.m.f. is 125; find the area of wire necessary and the B. & S. number. (*3 min.*)

5. A magnet requires 10,000 ampere-turns for its excitation. If the mean length of a turn be 15 inches, and it be run on a 110-volt circuit, required the area and the B. & S. number of the wire, resistivity to be taken as 12. (*3 min.*)

6. What must be the cross-sectional area in sq. cm. of a bar used in a horseshoe magnet to raise 500 pounds, taking B as 10,000? (*2 min.*)

7. A magnet with a round core 5 inches in diameter has 560 turns of No. 15 wire wound 1 inch deep. How many feet more of wire would be necessary if the core, having the same area, were rectangular with one side double the other. What per cent must the area of the wire be increased if the work of excitation is to be the same? (*6 min.*)

8. A magnetic circuit consists of 100 cm. of forged steel and $\frac{1}{2}$ cm. of air, with B equal to 16,000. Required the ampere-turns

necessary; also on a 110-volt circuit, the area and the B. & S. size of wire, if the mean length of turn is 12 inches, resistivity 12 and if 1000 circular mils per ampere be used; also the current and number of turns. (*6 min.*)

9. A 1-kw., 2-pole, 110-volt generator (1800 r.p.m.) has the following data for its magnetic circuit: Length of two air gaps, 0.6 cm.; density, 4400; length in armature, 13 cm.; density, 10,000; length in cast-iron field magnet, 80 cm.; area, 200 sq. cm.; total flux in armature, 1×10^6; leakage coefficient, 1.4; power to excite the field, 12%; mean length of a turn, 24 inches. Required the ampere-turns, size of wire and the number of turns necessary, taking resistivity as 12.5. (*5 min.*)

10. Given a round bar 3 inches in diameter, bent into a magnet, and having the length of magnetic circuit 15.75 inches. Find the number of turns necessary to give a pull of 2433 pounds with a current of 5.27 amperes. (*10 min.*)

11. Required to design a magnet for use on a 100-volt circuit, and to raise 2000 pounds. Resistivity is 12. Allow 1000 circular mils per ampere. B = 16,000. Use double cotton covered wire (see table, page 104). It is $3\frac{1}{4}$ inches between the insides of the shanks of the magnet, which are 4 inches long and are joined by a semicircular yoke; allow $\frac{1}{2}$ mm. air gap for the roughness of the iron piece to be raised, and 1 inch for the thickness of the winding. Find the diameter of the bar, area and B. & S. number of the wire, the number of turns and the current. (*30 min.*)

12. Design a magnet for use on a 110-volt circuit, to raise $2\frac{2}{3}$ tons with a factor of safety of $1\frac{1}{2}$. Length of the magnetic circuit in iron, 50 cm., and in air at joints, $\frac{1}{10}$ cm. Allow 1000 circular mils per ampere; the winding is 1 cm. deep; use cast steel with 16 kilogausses, and take the resistivity as 12. Required the number of ampere-turns necessary for the iron; the number of ampere-turns necessary for the air; diameter of the iron; and the area, size and total number of turns of wire. (*25 min.*)

13. A 440-kw., 10-pole, 500-volt (at no load), 85-r.p.m. generator has the following data for its magnetic circuit: Cast-iron yoke ($\frac{1}{10}$ of the ring), 130 cm. in length with a density, 7500; laminated cores, 45 cm. each in length with a density, 13,500; armature body ($\frac{1}{10}$ of the ring), 85 cm. in length; with a density, 9000; teeth, 4.5 cm. in length; with a density, 19,000; air gaps, 0.50 cm. in length; with a density, 16,000. The mean length of

the shunt turn is 79 inches and the total power taken by the shunt at no load is 1.34% of the output of the machine. Required the ampere-turns, the proper area of the shunt wire and the nearest B. & S. size; also the number of turns; take the resistivity as 12.5. (*16 min.*)

14. It is desired to build a magnet of rectangular cross-section, width equal to twice the breadth, and to be made of cast iron. Length of gap, $\frac{5}{8}$ inch; length of path in the iron, 35 inches; total induction, 3 megamaxwells; winding, 2 inches deep; density in gap, 7000. With wire at 20 cents per pound and iron at $2\frac{1}{2}$ cents, what is the cost of material, and will it be cheaper to use a density of 6000 or of 7000, and how much? Use No. 12 wire which runs 20.5 pounds per 1000 feet, and an exciting current of 10 amperes. Take the volume of the iron as area times length, and its weight as 0.26 pounds per cu. in. (*20 min.*)

15. An iron-clad magnet, to be used as a clutch, has a central pole 10 cm. in diameter, and a mean diameter of outside ring of 20 cm. Required the thickness of the cylindrical pole and the horse-power that the clutch will transmit at 500 r.p.m. if B be taken as 16,000, and if the normal pull is to be taken as ten times the tangential pull. Divide the central pole into a circle 2 cm. in diameter, surrounded by two rings each 2 cm. wide; take the torque as made up of that due to each of these taken at its mean radius, plus that of the outside ring at its mean radius. (*15 min.*)

CHAPTER VII

GENERATION OF ELECTROMOTIVE FORCE
ARMATURE DROP

1. Required the e.m.f. in volts of a conductor 18 cm. long, cutting a field of B, 9000, at a velocity of 1200 meters per minute. ($\frac{1}{2}$ *min.*)

2. A conductor on the surface of an armature is 50 cm. long and cuts through the magnetic field of density 9000 under a pole piece; the speed is 27 meters per second. What e.m.f. will be set up in it? (*1 min.*)

3. A rectangular coil having 85 turns, 20×40 cm., is moved in the direction of its long axis through a magnetic field at the rate of 12 meters per second. One of its short sides is outside of the field. The terminals of the coil are connected to an oscillograph which shows that the e.m.f. set up is 0.012 volts. What is the density of the field? (*1 min.*)

4. If the coil of the last problem were moved in a direction making 30 degrees with the axis of a field of density 8000, what would be the e.m.f. set up? (*1 min.*)

5. A 1-kw., 2-pole generator has 228 conductors and a speed of 2000 r.p.m. The flux is 1.6×10^6 maxwells; what is the e.m.f.? (*1 min.*)

6. A 2-pole, 8-kw., 125-volt generator has 180 conductors. The flux is 2.5×10^6. At what r.p.m. must the generator be run? (*1 min.*)

7. A 1000-kw., 16-pole, 500-volt generator is to run at 90 r.p.m. There are 2304 conductors. What must be the flux per pole, and what the area of the pole pieces with an air-gap density of 8600? (*2 min.*)

8. The copper loss in the armature of problem 7 is 24 kw. What increased voltage would the machine generate at full load in order to give 500 volts, at the terminals, and what per cent increase in the flux would be necessary? (*1 min.*)

9. There are 100 complete turns on a bipolar armature which

makes 1500 r.p.m.; the flux is 2×10^6. Required the current if the total resistance is 3 ohms. (*1 min.*)

10. A series machine has a resistance of 0.2 ohm. For 5 amperes the terminal e.m.f. is 99 volts; increasing the current to 10 amperes increases B from 10,000 to 15,000; required the e.m.f. at the terminals of the machine for a current of 10 amperes. (*1 min.*)

11. An armature core is 15 cm. in diameter; the shaft is 3 cm. in diameter; the net iron armature length is 15 cm.; the armature density is 12,000 and there are 100 conductors; required the e.m.f. at 2400 r.p.m. (*2 min.*)

12. A dynamo has 64 conductors; the length of the armature is 30 cm. and its diameter is 25 cm. The pole pieces cover three-fourths of the armature, and the density in the air gap is 10,000. Required the e.m.f. at 1000 r.p.m. (*2 min.*)

13. A 50-kw., 4-pole, 120-volt machine, designed to run at 680 r.p.m., is to have its speed reduced to 340 to permit of direct coupling to an engine. Its armature winding is made up of 128 bars, each 5×10 mm. What will be the values of the e.m.f., current capacity and power after this speed reduction? State what change must be made in the winding to bring the e.m.f. back to 120 volts, and what will then be the current capacity and power. The winding is to occupy the same space in both cases, neglecting insulation. (*3 min.*)

14. In the machine of problem 9, Chap. VI, it is required to increase the e.m.f. at full load to 135 volts. What per cent increase must be made in the flux in order to accomplish this? (*1 min.*)

15. A 250-volt, 40-kw., 4-pole generator has a 4-path winding of 272 conductors. By leaving out two of these conductors this winding may be changed to a 2-path winding. What would then be the e.m.f., current capacity and power of the machine? How much should the speed be increased to make up for the loss of the two conductors? (*2 min.*)

16. A 150-kw., 6-pole, 250-volt, 450-r.p.m. generator has 496 armature conductors, wound 6-path. If this were changed to a 2-path winding, what would its e.m.f., current capacity and power rating become? What would be the e.m.f. generated in one conductor? (*2 min.*)

17. The resistance of the 6-path armature, including brush drop of problem 16, is 0.0081 of the series coil 0.00083, and of the

shunt field 61 ohms. What e.m.f. will have to be generated at full load in order to get the 250 volts at the terminals? If the flux were kept constant in this machine from no load to full load, what would be the regulation expressed in per cent at the rated voltage at full load? By what per cent must the flux density be increased to maintain a constant voltage? (*2 min.*)

18. The armature of a 30-kw., 110-volt, 4-pole machine is wound multiplex with two bar windings of 156 conductors each. By changing the method of connection to the commutator and without other change this may be made a single winding. What will then be the e.m.f., current capacity and power rating of the armature? (*1 min.*)

19. A maker uses the same armature core for 125 and 500-volt machines of the same watt capacity. At 125 volts there are 144 turns of No. 8 wire. Specify the number of turns and the B. & S. number for the 500-volt machine of the same speed. The winding is to occupy the same space neglecting additional space taken by the insulation. (*1 min.*)

20. A 4-path armature has 42 slots with wire space $\frac{1}{4} \times \frac{1}{2}$ inch, and each slot contains 8 No. 8 wires. The e.m.f. is 120 volts. This armature is rewound with No. 14 wire, putting in as many conductors in a slot as possible. Required the e.m.f. in the second case and the power in both cases, using 600 circular mils per ampere. The speed remains constant. (*4 min.*)

21. If a unipolar dynamo runs at 6000 r.p.m. and the strength of field is 16,000 gausses, what must be the diameter of the disk to generate 5 volts, the inside diameter being 4 inches. (*3 min.*)

22. A certain 110-volt shunt generator when run at 0.8 normal speed gives 65 volts. What percentage change has taken place in the flux? When run at 20% above normal speed the voltage is 145; what is the change in the flux? (*4 min.*)

23. A 4-pole generator has a speed of 1500; the length of the armature is 15 cm. and its diameter is 25 cm. The pole covers 60 degrees. The armature is 4-path and has 31 slots each containing 8 conductors of No. 10 wire. The gap density is 10,000. Required the e.m.f. generated and the output in kilowatts with 400 circular mils per ampere allowed in the armature winding. (*4 min.*)

CHAPTER VIII

ARMATURE WINDINGS

The three usual methods of depicting an armature winding are by the winding table, the development and the radial or end-view diagram. Give all of these for each of the following cases, as assigned. Also show the location of the poles and brushes in each case. Coördinate paper is convenient for making the developments.

Problem.	Poles	Paths	Conductors	Right or left hand	Com. Segments.	Type	Time
1	2	......	26	Right	13	Simplex	10 min.
2	2	......	36	Left	18	Simplex	10 min.
3	2	......	72	Right	18	Simplex	10 min.
4	4	4	36	Right	18	Simplex	10 min.
5	4	2	26	Left	13	Simplex	10 min.
6	4	2	52	Right	13	Simplex	10 min.
7	6	6	36	Right	18	Simplex	10 min.
8	6	2	40	Left	20	Simplex	10 min.
9	4	4	36	Right	20	Duplex	20 min.

Note. — Armature windings may be studied advantageously with the aid of small wooden models, say about three inches in diameter by one inch long. Upon the cylindrical surface of these saw cuts are made to represent the slots. On the front end of this model may be a boss one inch in diameter and about $\frac{3}{4}$ inch long, to represent the commutator, with small brads driven in opposite alternate slots to mark the segments and serve for the attachment of a winding of thread. It is also well to have a small boss on the back side to represent the shaft. The following problems are based upon such model armatures, having 26 and 36 slots respectively:

10. Put the winding of problem 1 on the proper model using thread. Take this off and wind on the corresponding left-hand winding. (*8 min.*)

11. Same as problem 10 except that the winding of problem 2 is to be used. (*8 min.*)

12. Same as problem 10 except that the winding of problem 4 is to be used. (*8 min.*)

13. Same as problem 10 except that the winding of problem 5 is to be used. (*8 min.*)

14. Same as problem 10 except that the winding of problem 7 is to be used. (*8 min.*)

15. Same as problem 10 except that the winding of problem 9 is to be used. (*10 min.*)

CHAPTER IX

ARMATURE-CIRCUIT CALCULATIONS, RESISTANCES, CURRENT CAPACITY, ETC.

1. In a certain dynamo the armature resistance is 0.1 ohm; when giving 50 amperes it actually generates 105 volts; what is the e.m.f. at the terminals? ($\frac{1}{2}$ *min.*)

2. A bipolar machine having an armature with 48 segments generates at full load an actual e.m.f. of 115 volts; the resistance (brush to brush) is 0.037; with 93 amperes delivered by the armature, what will be the average difference of potential per segment? (*1 min.*)

3. In the above problem what is the actual resistance between two adjacent commutator bars? ($\frac{1}{2}$ *min.*)

4. A 2-pole armature is wound with 550 turns, each including three feet of No. 10 wire. Required the resistance from brush to brush at 70° C. (for resistivity see table on page 104). Also find the current output of the armature at 600 circular mils per ampere. Also the armature drop with this current. (*2 min.*)

5. Required the resistance and the current output, if the above armature be connected for a 4-pole, 4-path (parallel-wound) machine. Also for a 6-pole, 2-path (series wound). Also for a 10-pole, 10-path machine. (*4 min.*)

6. A 2-path armature is wound duplex for 250 volts. Each winding is made up of 199 turns of 4 feet each of No. 12 wire. For 500 volts the coils of the two windings are simply put in series by changing the connections at the commutator segments. Required the resistances in both cases for 40° C. For the same current density how does the power lost in the armature winding in the two cases compare? (*3 min.*)

7. If there is a difference of 3 volts in the e.m.f.'s set up under the poles in a 2-pole generator, the armature resistance being 0.2 ohm and the total current through the two sides being 27 amperes, what current will flow under each pole? What current will flow when the outside circuit is open? (*2 min.*)

8. By test a bipolar shunt generator gives 90 volts and 25 amperes to the outside circuit; if the resistance of the armature be 0.324 ohms, the resistance of the field be 41.0 ohms, required the current through the armature conductor and the B. & S. size if 500 circular mils per ampere be used. Also the total e.m.f. generated by the armature. (*2 min.*)

CHAPTER X

ARMATURE REACTIONS

1. A bipolar armature has 420 conductors, and its field has a polar angle of 120 degrees. When it is giving 100 amperes from the brushes, how many cross and how many back ampere-turns will be present, supposing that the brushes are placed opposite the pole tips? (*1 min.*)

2. The pole pieces of a bipolar generator subtend 108 degrees each, and the armature has 63 slots with 4 conductors each. If the brushes are opposite the pole tips, how many cross and how many back turns will be present? If the machine is giving 40 amperes, how many cross and back ampere-turns will there be? (*1 min.*)

3. A 4-pole, 55-kw., 125-volt, 4-path (parallel-wound) generator has poles subtending 60 degrees each. There are 100 slots with two conductors each. What will be the back and cross ampere-turns when the machine is giving its full load if the brushes are opposite the pole tips? If the connections of this armature be changed so as to use it in a 2-pole field having the same total area of pole face, what will the cross and back ampere-turns become? The same current density is used in the conductors. (*2 min.*)

4. A 100-kw., 250-volt, 8-pole generator has an armature circumference of 360 cm. The width of each pole face is 36 cm., there are 167 slots with two conductors each, and they are connected as a 2-path (series) winding. How many cross and back ampere-turns are present at full load with the brushes opposite the pole tips? How many would there be if the same conductors used at the same current density could be connected as an 8-path (parallel) winding? How many if the same conductors were reconnected and used in a 2-pole field with the same total polar area? (*2 min.*)

5. If in problem 1 the gap density be 8000 and the density due to the cross field must not exceed 75% of the gap density, what will be the smallest permissible length of gap? How much could this be reduced if the machine were 4-pole? (*1 min.*)

6. If the flux be 3×10^6, the reluctance of the whole circuit be 0.001 and there be ten back turns, required the total number of ampere-turns on the field necessary if the armature be giving 48.6 amperes. (*1 min.*)

7. A bipolar smooth-core machine has an air gap of $\frac{3}{8}$ inch, a gap density of 12,000, a polar angle of 135 degrees and 200 conductors. How much current could be taken from the machine without reversing the field under the pole tips? (*4 min.*)

Note. — On account of their greater simplicity most of the problems involving length of air gap are given as applying to the old-style smooth-core machines. The flux conditions in the gap and teeth of a slotted core dynamo are too complicated to lend themselves readily to problems of this kind. The principals involved are, however, similar.

8. Given the following data of a 2-pole machine: the number of conductors is 320, the gap density is 6000; the length of gap (two sides) is 1.6 cm.; 80% of the surface of the armature is covered by the poles. If the cross ampere-turns are not to exceed 0.6 of the part of the field ampere-turns applied in the gap, how much current can the above armature carry? How much if only 75% of the surface of the armature be covered by the poles? (*3 min.*)

9. A 110-volt shunt dynamo has 1130 field turns with a shunt resistance of 55 ohms. There are 120 armature conductors and a 20-degree angle of lead. The polar angle is 120 degrees. The machine is feeding 132 15-watt lamps. Required the cross, back and effective ampere-turns. (*3 min.*)

10. Determine the number of cross ampere-turns per pole, back ampere-turns per pole and series turns per pole to balance the back turns in the case of a dynamo having the following data: Conductors 500, total current 200, 4-pole, 2-path winding, polar angle 60 degrees, angle of lead 10 degrees, 0.9 of the total current flowing through the series turns; leakage coefficient, 1.3. (*4 min.*)

11. Given a 4-pole smooth-core dynamo, with the polar angle 60 degrees, angle of lead 12 degrees, 240 conductors, current (total) 824, 4-path winding, leakage coefficient 1.25; required the series turns per pole necessary to balance the back turns; also the minimum thickness, in inches, of the air gap without possible reversal of the field under the pole tip, if the gap density be 10,000. If this machine were bipolar with $\frac{1}{2}$ the total current and double the polar angle, what would the above quantities be? (*4 min.*)

12. A 2-pole armature has 64 segments, two turns per segment. The total current is 120; angle of lead 25 degrees; brushes opposite pole tips. The gap density is 10,000 and the leakage coefficient, 1.35. Required: (*a*) The cross ampere-turns. (*b*) The back ampere-turns. (*c*) The series turns necessary to balance the back ampere-turns if 0.8 of the total current be used in the series winding. (*d*) The least thickness of air gap that could be used without reversing the field under the pole tip (cm.). (*e*) The same quantities if the polar angle be increased to 145 degrees. (*f*) Also if, with 290 degrees covered by the pole pieces, the machine be made a 4-pole machine with a 2-path winding, find values for each magnetic circuit. (*g*) Also the gap thickness in the first case if the gap density be reduced to 8000. (*12 min.*)

13. In a smooth-core machine, if the density due to the field winding be 7000 and the length of one air gap 0.8 cm.; if there be 260 conductors and the polar angle be 125 degrees; plot the curves of density across the pole face with 0, 50 and 200 amperes given by the armature. (*12 min.*)

14. If in the machine of problem 3 the slots be 2.4 cm. deep and the tooth density 20,000, also if the clearance be 2 mm. and the density above the teeth be on account of the spreading of the lines 80% of the tooth density, also neglecting all other conditions than the effect of reluctance on the circuit of the cross-magnetization (through the teeth under the tips), what current would reduce the density under the leading pole tip to 75% of its no-load value? (*5 min.*)

Note. — The effect of the unequal reluctance under the two tips would effect the distribution of the main field, thus requiring a still larger current to produce the proposed change in density.

CHAPTER XI

MAGNETIZATION CURVES

1. A 4-kw., 110-volt, 2-pole generator (1300 r.p.m.) with a cast-iron field, has lengths and cross-sectional areas of its magnetic path as follows: In the field, 110 cm., 470 sq. cm.; 2 gaps, 7 mm., 540 sq. cm.; armature, 20 cm., 165 sq. cm. The leakage coefficient is 1.3. Plot magnetization curves for the gap, the armature, the field and hence for the whole machine. Plot in terms of total armature flux and field ampere-turns obtaining five points by steps of 500,000 each. Give also on the same curves, scales of e.m.f. and field current; the field turns being 2400 and the number of armature conductors 216. From the curve determine the armature flux at no load. Find also the field currents to give 80, 100 and 120 volts at no load. (*40 min.*)

2. A 150-kw., 6-pole, 250-volt generator, 450 r.p.m. (same as in problem 6, Chap. XIV) has the following data for its magnetic circuit: Yoke, cross-sectional area, 284 sq. cm., length, 66 cm.; cores, area, 506 cm., length, 35.5 cm. each; armature, area, 684 sq. cm., length, 38 cm.; teeth, total area under pole face, 413 sq. cm., length, 4.1 each; gaps, area increased on account of spreading to 658 cm., length, 0.8 cm. each; leakage coefficient, 1.17. Plot magnetization curves for the field, gaps and armature, and from these for the whole machine, obtaining four points for armature fluxes equal 1, 3, 5 and 7×10^6 lines. If there are 1800 field turns per pole and a total of 496 armature conductors, wound 6-path, lay off scales for field current and generated e.m.f. Find the field current for 200, 250 and 275 volts at no load. The field is all of cast steel. (*50 min.*)

3. It is desired to use the machine described in problem 1 over-compounded so that at full load it will generate 10% more voltage. What per cent must the ampere-turns be increased to do this? It is also desired to use this same machine to fill a special order for a 90-volt machine to overcompound 10% at full load. What ampere-turns will be needed at no load, and by what per cent must they be increased at full load? (*5 min.*)

Note the difference in these two cases due to the shape of the curve.

4. Plot a curve to show the effect on the magnetization curve of using in problem 1 a toothed core armature with a clearance of 0.3 cm. Assume the teeth to be 1.5 cm. long and to occupy 50% of the area under the pole face. (*30 min.*)

5. To maintain the same voltage in the generator of problem 2, if its speed were to be decreased to 425 r.p.m., what change in the field ampere-turns would be necessary? Also if the speed were to be increased to 475 r.p.m.? (*5 min.*)

6. The machine of problem 2 has an armature resistance of 0.0081 and the equivalent demagnetizing turns on the armature are 28. Determine from the magnetization curves the ampere-turns and the field current necessary to operate the machine at full-load current and voltage. Also the voltage necessary on the field to give this field current, the shunt-field resistance being 61 ohms. Could the generator be operated as a plain shunt machine? (*4 min.*)

7. Determine from the data given in problem 6 the number of series turns needed to operate this machine as a flat compound and also as a 10% over-compound generator. (*3 min.*)

CHAPTER XII

CHARACTERISTICS

Note. — In plotting always use the same scale for abscissæ and ordinates.

Unless otherwise stated "armature current" means the combined current of all the parallel paths, and "armature resistance" means the resistance from brush to brush.

1. Assuming that a certain magneto generates a constant e.m.f. of 60 volts regardless of load, and has an armature resistance of 120 ohms, what current will it give when short circuited? With what current will it give 50 volts at the terminals? ($\frac{1}{2}$ *min.*)

2. Required the e.m.f. generated and the current in the armature in each of the following cases:

(*a*) A 100-ohm magneto sends 0.1 ampere through 1000 ohms resistance.

(*b*) A shunt machine having field and armature resistances, 50 and 0.01 ohms, supplies 50 100-volt 40-watt lamps connected in parallel. (*1 min.*)

3. Required the e.m.f. generated and the current in the armature in the two following cases:

(*a*) A series machine supplies ten 45-volt 10-ampere lamps through a line having 5 ohms resistance; the field and armature resistances are 0.2 and 0.3 ohms.

(*b*) A long-shunt compound generator gives 500 volts and 50 amperes; the armature and series and shunt-field resistances are 0.03, 0.02 and 500 ohms. (*1 min.*)

4. The curve of generated e.m.f. with current, i.e. the total characteristic of a separately excited generator, is given by the following points:

Current........	0	20	40	60
E.m.f..........	110	109	107	104

The armature resistance is 0.05 ohm.

Construct the above curve and derive the external characteristic. (*5 min.*)

5. A 10-kw., long-shunt, compound generator has armature, shunt and series-field resistances 0.05, 22 and 0.03 ohms. It is supplying at its terminals 200 55-watt 110-volt lamps. Required the total generated e.m.f. and the total armature current. (*1 min.*)

6. If the machine of problem 5 is connected as a short shunt with the same terminal e.m.f., required the generated e.m.f. and current. (*1 min.*)

7. If the generator in problem 5 has a regulating "shunt" of 0.1 ohm resistance, in parallel with its series turns, how will the series ampere-turns be changed? (*1 min.*)

8. A long-shunt, compound, 80-kw. generator is supplying through a feeder having 0.2 ohm resistance the following load: A 220-volt motor taking 22 kw. and 1100 16-c.p., 220-volt carbon lamps taking four watts per candle power. The armature resistance is 0.02 ohms, and the shunt and series-field resistances are 22 and 0.01 ohms. Required the armature current and the generated e.m.f. (*2 min.*)

9. The following data are obtained from a test of a shunt machine:

Volts	110	100	90	80	70	60	50	40
Amperes	0	40	59	65	67	65	59	50

The armature and field resistances are 0.12 and 30 ohms. Plot this curve, and from it plot the total characteristic. (*10 min.*)

10. Given the following data for a series external characteristic:

Volts	20	40	60	80	100	120	132	135	133	120
Amperes	10	19	26	35	45	60	80	100	120	150

$R_a = 0.1$ and $R_f = 0.05$. Plot this curve, and from it plot the total characteristic. Also plot the latter curve if the speed be increased 20%. (*10 min.*)

11. Given these data for a shunt total characteristic:

Volts	143	140	136	130	120	110	90
Amperes	10	22	40	60	70	75	78

Plot this curve and from it plot the external characteristic, having given $R_a = 0.08$, $R_s = 30$. (*10 min.*)

12. Given the following data of an external shunt characteristic:

Volts	216	207	197	187	175	161	146
Amperes	0	4	8	12	16	20	24

$R_a = 0.4$ and $R_s = 80$. Plot this curve and from it the total characteristic. (*10 min.*)

13. Plot the external straight-line characteristic of a 550-volt (at full load), 110-kw., compound-wound, short-shunt generator, over-compounded 10%. If $R_a = 0.09$, $R_f = 0.04$, $R_s = 100$, plot also the total characteristic. (*10 min.*)

14. A 450-kw., compound generator, long shunt (85 r.p.m.), gives 500 volts on no load and is over-compounded 10%. $R_a = 0.018$, $R_f = 0.0055$. The full-load shunt current is 10.5 amperes. Construct the external and total characteristics. (*10 min.*)

CHAPTER XIII

HEATING AND RATED CAPACITY OF DYNAMOS

1. If a cylindrical coil 6 inches in diameter and 10 inches long has a resistance of 8 ohms, and a current of 5 amperes is passed through it, what will be the final temperature, if there be radiated 0.01 watt per sq. in. per degree F.? (*2 min.*)

2. If the coil of a magnet with the same character of surface as above were 4 inches in diameter outside and 5 inches long, how many watts could be allowed in the same, if its maximum temperature above the atmosphere is to be 80 degrees? Figure only the cylindrical surface as radiating. If operated on a 10-volt battery, what resistance must the coil have? (*2 min.*)

3. A rectangular field coil 10 × 16 inches carries a current of 10 amperes and has a drop of 40 volts. The surface being such that $\frac{1}{300}$ watt is given off per sq. cm. and degree centigrade, how long must the coil be, not to have a rise of more than 40 degrees above the temperature of the air? (*2 min.*)

4. For an armature of a certain type and speed there are 0.02 watt radiated per sq. in. per degree F. (area taken as two complete ends and the cylindrical surface). The diameter is 10 inches and the length 8 inches. The resistance is 0.04 ohm, and the hysteresis and eddy loss is 300. What is the temperature rise on a full load of 100 amperes. (*2 min.*)

5. The type and speed of a 10-pole, 550-kw., 550-volt generator (90 r.p.m.) are such that a rise of temperature of 85° C. in the armature would dissipate one watt per sq. cm. If the available radiating surface of the armature is 78,500 sq. cm., the resistance 0.0125 and the iron loss 11,000 watts, required the temperature at full load.

What would be the capacity of this machine if rated in accordance with the A.I.E.E. standardization report? (*4 min.*)

6. A 6-pole, 150-kw., 250-volt generator (same machine as in problem 2, Chap. XII, 450 r.p.m., peripheral velocity 2840 ft. per minute) has an armature surface of such a character that it radiates $\frac{1}{25}$ of a watt per square inch and per degree centigrade

temperature rise. The armature resistance is 0.008; the hysteresis loss in the teeth is 620 watts and in the body 1140; the eddy current loss in the teeth is 70 and in the body 130. The radiating surface is 2500 square inches. Required the temperature rise.

What would be the capacity of this machine if rated in accordance with the A.I.E.E. standardization report? (*4 min.*)

CHAPTER XIV

DYNAMO LOSSES AND EFFICIENCIES

1. A 10-kw., 110-volt, 2-pole shunt generator has the armature resistance 0.04 and the shunt field 22. Required the copper loss at full load. The field rheostat resistance is 15 ohms. If the machine gives 110 volts at no load with this resistance all in, required the no-load copper loss under these conditions. (*4 min.*)

2. A 500-kw., 550-volt generator requires 2.10 volts to send 200 amperes through its armature when at rest. What will be the armature copper loss when giving its full-load current of 910 amperes at 550 volts? (*3 min.*)

3. A 500-volt, 4-pole, 35-kw. generator (500 r.p.m.) has resistances as follows: Armature, 0.3; shunt field, 200; series, 0.15. Required the copper loss for a load of 60 amperes. (*4 min.*)

4. If in the generator of problem 1 the iron losses constitute 2%, and the friction loss 3% of the rated output, required the efficiency at full load. Also for $\frac{1}{2}$ load, assuming the speed to remain constant, and that 8 ohms of the rheostat are in the field circuit. (*3 min.*)

5. In the generator of problem 3 if the hysteresis loss be 140 watts, that due to eddy currents, 50 watts, and if the friction loss be $7\frac{1}{2}$% of the rated capacity, required the efficiency of the machine for a load of 60 amperes. (*2 min.*)

6. If the machine of problem 6, Chap. XIII, has a brush-contact resistance = 0.003, series-field resistance = 0.0008 and shunt-field resistance = 60, required the total copper loss for no load and for full load. (*4 min.*)

7. If in problem 6 the total friction loss be 5 kilowatts, required the full-load and half-load efficiency. (*6 min.*)

8. In the generator of problem 6, Chap. XIII, the outside diameter of the armature disks is 83.5 cm., the inside diameter 45.7 cm., the depth of a slot 4.13 cm., and the iron length of the core 22.8 cm. Also the mean density is 10,700. Required the hysteretic constant to give the hysteresis loss as stated in watts. (*10 min.*)

9. The thickness of the disks in the generator of problem 8 is

20 mils. Required the eddy current constant to give the stated loss in watts. (The thickness is to be kept in mils.) (*10 min.*)

10. A 110-volt, 100-ampere armature has a resistance of 0.025 ohm. Plot a curve of loss in the conductors with current; give the equation for the resulting curve and its name. If the machine be a long shunt compound, 100-volt generator, with the series-field resistance 0.01 and the shunt-field resistance 25, plot the field losses and the total copper loss with current in the outside circuit as abscissæ. (*10 min.*)

11. A 1000-kw., 1000-volt generator has 1000 r.p.m. rated speed. The armature resistance is 0.106 ohm. When run as a motor with normal field strength it takes 925 volts on the armature to give normal speed and the armature current is 22.2 amperes. What is the stray power? (*4 min.*)

12. In the generator of problem 11 the other resistances are series field, 0.002; interpole, 0.0035; the shunt current is 2.24 amperes and the brush drop (both sides) is 2.8. Required the efficiencies for $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$, 1 and $1\frac{1}{4}$ load. Plot these as a curve with output as abscissæ. (*15 min.*)

13. A 100-volt shunt motor has the resistance of the armature 0.03 and of the shunt 20 ohms. The full load on the armature is 10-kw. input. When the motor is run on no load at full-load speed, the armature takes 4 amperes at 90 volts. Required the full-load efficiency. Neglecting the change in stray losses, find also the $\frac{3}{4}$, $\frac{1}{2}$, $\frac{1}{4}$ and $\frac{1}{10}$ load efficiencies and plot with input. (*15 min.*)

14. A test of a $2\frac{1}{2}$-h.p., 110-volt shunt motor gives the following resistances: Armature 0.3, field 55.

The results of the speed load test are:

ARMATURE

Speed.	Amp. Input.	Speed.	Amp. Input.
1955	21	2010	19
1985	20	2030	18

The results of the iron- and friction-loss test are:

Speed.	Armature current.	Armature volts.
1950	1.59	95
1975	1.65	98
2000	1.72	103
2025	1.80	108

Plot a curve of efficiency and output and find from it the efficiency for 2.2-h.p. output. (*15 min.*)

15. A 120-volt shunt motor is giving, as determined by a brake, an output of 23 h.p. It is then absorbing 20.2 kw.; the field current is 5.3 amperes and the armature resistance is 0.031 ohm. What is the efficiency and power intake when the motor is giving 10 h.p.? (*10 min.*)

16. The following data is given with regard to the armature of the 500-kw. generator of problem 2.

Volume of iron in body of core, cu. cm.	97,800
Volume of iron in teeth	26,050
Density in body of core	17,000
Density of teeth, mean	21,000
Speed, r.p.m	330
Poles	8
Hysteresis constant, for watts	2×10^{-10}
Eddy loss	9350

Determine the total iron loss for the armature. (*8 min.*)

17. The shunt field of the 500-kw. generator of problem 16 has a hot resistance of 89 ohms, the series field of 0.0022 and the interpole winding of 0.0012, the brush drop at full load is 1.6 volts, and the brush friction 2280 watts. The bearing and windage friction loss is 3500 watts. Required the one-half load and full-load efficiencies. (*10 min.*)

18. A 105-volt, 4-pole dynamo gives the following data: r.p.m., 750; gap density, 13,000; full-load current, 300 amperes; length of armature core, 50 cm.; outside diameter, 25 cm.; and inside diameter, 7.5 cm. The temperature at which the machine is to run is 64° C. The shunt field is wound with 2.25 kilometers of No. 11 wire. The armature resistance is 0.005 ohm, at 14° C. The drop through the brushes and connections at full load is $\frac{1}{2}$ volt. The hysteresis loss in the armature is 880 watts per cubic meter, at one cycle per second. The friction loss is 400 watts. The eddy current loss is 2 watts per cubic meter, at one cycle per second. Required the iron loss, copper loss, total loss and efficiency at full load. (*15 min.*)

19. In a brake test upon a 30-kw., 500-volt motor, 52 amperes are supplied, the motor is making 1000 r.p.m., and the load on the 3-foot brake arm is 55 lbs. Required the efficiency of the motor.

What change in the length of the brake arm could be made to facilitate the computation of the horse-power? (*2 min.*)

20. A rated motor is being used as a dynamometer to measure the power absorbed by a printing press. The iron losses are 450 watts, the field resistance 493 ohms and the armature resistance 0.53 ohm. The voltmeter reads 512 volts and the ammeter in circuit with the machine 21.3 amperes. What power is the motor furnishing to the press? (*5 min.*)

21. The motor of problem 13 is to be used to drive a group of tools in a machine shop. All the tools, including a punch press, are in operation one hour per day and require 10 h.p. Shutting down the press reduces the load to 5 h.p., at which it runs 6 hours. During the remaining 2 hours of the working day only 2 h.p. are required, and for an hour at noon only 1 h.p. is used. Plot a curve of total loss with output for the motor and hence determine its all-day or energy efficiency. (*15 min.*)

22. Two 550-volt, 1600-kw. compound dynamos are coupled together, and are being tested by the Knapp method, that is the power for the losses is supplied electrically. The shunt-field currents of the motor and generator are 26.1 and 26.9 amperes. The armature resistance of each machine is 0.0037 ohm, and the average of the armature currents is the rated full-load current. The stray losses are assumed equal in the two machines. 322 amperes are being supplied from outside. What is the efficiency of each machine? (*10 min.*)

CHAPTER XV

MOTORS

1. A wire 40 cm. long and carrying 100 amperes lies in a field of 5000 gausses. Required the force acting on the wire in dynes. (*1 min.*)

2. A 2-pole motor has an armature diameter of 8 inches and an armature length of 10 inches; the polar angle is 120 degrees and the width of the pole is equal to the armature length; there are 220 conductors and the density in the gap is 4500. Required the horse-power converted by the motor at 1200 r.p.m., and when taking 40 amperes in the armature. (Neglect the fringing.) (*5 min.*)

3. The following data refer to a 4-pole, 4-path, 220-volt motor taking 140 amperes in its armature and running at 750 r.p.m.:

Armature diameter	15 inches
Armature length	11 inches
Armature conductors	300
Polar angle	72 degrees
Gap density	7500

Required the horse-power converted and also the horse-power output, if the iron losses constitute 3% and the friction loss 2% of the output. (*7 min.*)

4. What horse-power is being converted by a motor having 124 conductors on a $6'' \times 6''$ armature, the poles covering 120 degrees each, and the total flux being 1.94×10^6 when the armature current is 22 amperes, and the speed is 1500 r.p.m. (*3 min.*)

5. A shunt motor has 220 volts applied and takes 52.2 amperes. The field resistance is 110 ohms and the armature resistance is 0.2 ohm. Required the counter e.m.f. Also if the total flux is 2.72×10^6, and the number of conductors 300, required the number of revolutions per minute. (*3 min.*)

6. A shunt motor on a 110-volt circuit, having an armature resistance of 0.25 ohm, runs on no load at 1150 r.p.m., and at a full load of 30 amperes at 1120. With 30 amperes how much

resistance would have to be put in series with the armature to reduce the speed to 565 r.p.m.? If, with this resistance in circuit, the current be next reduced one-half, what will the speed become? (*7 min.*)

7. A 2-pole, 110-volt motor with a full-load armature current of 90 amperes, has an armature resistance of 0.08 and 300 conductors; and the total flux is 3.4×10^6. Required the no-load speed, the full-load speed, and the per cent that the drop in speed is of the full-load speed (the regulation). The brushes are midway between the poles, and the no-load current is 3 amperes. (*4 min.*)

8. In problem 7 if the armature resistance were doubled, what would be the speeds and the per cent regulation? Also what would be the speeds and regulation if by reducing the field current the flux were reduced to 3×10^6? (*5 min.*)

9. If in problem 7 a resistance of 0.2 ohm be placed in the armature circuit for the purpose of reducing the speed, what will the no-load and the full-load speeds become? What per cent of the power used will be consumed in the resistance at full load? (*5 min.*)

10. A 4-pole, 2-path, 220-volt, 24-h.p. motor has a full-load current of 95 amperes. The field current is 5 amperes, the armature resistance is 0.03, the flux is 4×10^6 and the conductors, 160. The brushes are midway between the pole pieces and the no-load current is 4 amperes. Required the no-load and full-load speeds, and the per cent regulation. (*5 min.*)

11. What will the regulation in problem 10 become if the brushes are drawn back so as to produce back ampere-turns which reduce the flux 2%? What would the flux have to be made in order to reduce the full-load speed 10%? (*2 min.*)

12. How much resistance would have to be put in the armature circuit of problem 10 in order to reduce the speed one half? What would the regulation from no load to full load become then? What per cent of the power supplied would be lost in the resistance? (*6 min.*)

13. In problem 10 how much starting resistance would have to be put in series with the armature if the starting current were not to exceed the full-load current? If the motor were carrying half load current, what speed would it reach with this resistance in the circuit? How much resistance could be cut out, allowing the current to again reach full-load value? (*7 min.*)

14. A 4-pole, 220-volt, 25-h.p. shunt motor is wound with a 2-circuit winding of 344 conductors in 43 slots, and runs light at 800 r.p.m. The dimensions of the conductors are 90 $\times$ 200 mils. It is desired to use this frame for a 400-r.p.m. 110-volt motor. Specify two windings which will accomplish this. The field is wound with 2200 turns per spool of wire 46 mils in diameter. Specify the changed winding necessary. (*4 min.*)

15. The resistance of the armature (unchanged) of problem 14 is 0.067 ohm. The efficiency of the motor being 91% and the field current 1.7 amperes, what will be the speed with rated load? (*7 min.*)

16. The magnetization curve for a 440-volt, 10-h.p., 4-pole, 800-r.p.m. (at no load) shunt motor, is given by the following data:

Ampere-turns........	1000	2000	3000	4000
Maxwells $\div 10^6$	0.53	0.97	1.24	1.48

The normal ampere-turns are 2500 for 440 volts. At what speed will the motor run with no load on a 330-volt circuit, and also on a 550-volt circuit? Neglect changes in the resistance of the shunt winding. (*7 min.*)

17. The normal resistance of the shunt motor in problem 16 at 60° C. is 25 ohms. At what speed will the motor run when started up out of doors at − 20° C.? (*4 min.*)

18. The motor of problem 16 has its field rewound with wire of double the area so as to make it available for variation of speed by the field rheostat. What must be the resistances in the rheostat when the motor is running at 600 and 1000 r.p.m.? (*4 min.*)

19. If in problem 16 the armature resistance is 1.4 ohms, at what speed will the motor run with rated load on the 440-volt circuit? (*3 min.*)

20. A 6-pole, 500-volt shunt motor with a 6-path armature has a full load of 300 amperes. The armature resistance is 0.032 ohm, and the total flux at no load is 8.96×10^6. The armature has 978 conductors, and the field excitation is 15,000 ampere-turns per pair of poles. Assuming the brushes to be midway between the poles, required the speed in r.p.m. for currents of 5 and 300 amperes in the armature. (*4 min.*)

21. A 440-volt, 850-h.p., 100-r.p.m., 14-pole motor has a parallel-wound armature, a full-load current of 1550 amperes, and

an active conductor length of 33 cm. The mean density in the slots is 3600. With how many pounds does the conductor press against the side of the slot? If the area of the air gap is 1360 sq. cm. and the total flux is 15.5 megamaxwells, what would be the pull on the conductor if the armature were smooth core? *(4 min.)*

22. A 220-volt shunt motor is to be used as a dynamometer to measure the power taken by a lathe making a heavy cut. The speed is 1060, the current is 23.2, and the voltage on the armature is 218. With 218 volts on the field and 209 on the armature it runs without load at 1060 r.p.m. and takes 1.7 amperes. The resistance of the armature is 0.62 ohm. Required the power taken by the lathe. *(5 min.)*

23. Two 10-h.p., 1200-r.p.m., 220-volt motors are mechanically coupled and have their armatures connected in series on a 220-volt circuit. The fields are each normally excited. At what speed will the motors run, and how many horse-power will the combination produce? *(2 min.)*

24. Same as problem 23, except that one motor is a 220-volt and the other a 110-volt motor. *(3 min.)*

25. Same as problem 23, except that the field strength of one motor is increased 25%. *(4 min.)*

26. A 4-pole, 2-path, 500-volt series motor has a full-load rating of 20 amperes. The armature and field resistances are 1 and 1.4 ohms and there are 920 conductors. The field turns per pair of poles are 300. Its magnetization curve is as follows:

Ampere-turns . . .	3000	4000	5000	6000	7000	8000	9000
Megamaxwells . .	1.76	2.27	2.72	3.02	3.14	3.25	3.34

Required the speed for half load, full load and 50% over load. The brushes are midway between the pole tips. *(6 min.)*

27. If a resistance of 10 ohms is put in series with the motor of problem 26, at what speeds will it run with full-load current and with half-load current? *(3 min.)*

28. If a shunt of 1.4 ohms is put around the field in problem 26, at what speed will it run when taking 20 amperes in the armature? *(2 min.)*

29. Given a 4-pole, 500-volt, 35-h.p. railway motor with a 2-path winding, 44 field turns per pole, 744 armature conductors, armature resistance 0.32 and field resistance 0.168. The brushes

are set midway between the pole tips. The magnetization curve is as follows:

Flux per pole......	1×10^6	2×10^6	3×10^6	3.5×10^6	4×10^6
Ni, per 2 poles.....	1160	2180	3400	4200	5250

Find the speeds for 2, 30 and 60 amperes. (*10 min.*)

PART II

ALTERNATING-CURRENT CIRCUITS AND APPARATUS

PART II

CHAPTER I

INDUCTANCE AND INDUCED E.M.F.

1. A current of 25 amperes changes in $\frac{1}{10}$ of a second to 5 amperes; required the rate of change of the current during this time. ($\frac{1}{2}$ *min.*)

2. When five amperes flow through a circuit surrounding an iron ring, there is a flux of 10^5 maxwells; when the current is increased to 10 amperes, the flux increases to 1.6×10^5. Required the average rate of change of flux with current within the above current limits. ($\frac{1}{2}$ *min.*)

3. During the first 10 minutes a man goes $1\frac{1}{2}$ miles, during the next 20 minutes he goes 2 miles and in the next half hour he goes $1\frac{1}{2}$ miles. What are his average speeds, or rates of change of distance with time, during the first 30 minutes and during the whole time? Assuming a regular decreasing speed, what is his instantaneous speed at the end of 20 minutes? (*1 min.*)

4. At a certain point in a city property sells for $120 per front foot. Half a mile farther out its value has dropped to $80, at 1 mile it is $60, at 2 miles it is $30 and at 3 miles $20. Find the average rate of change of value with distance within the above limits. Find also the rate (instantaneous) at which values are changing at the 2-mile point. (*5 min.*)

5. A ring is built of wrought-iron rod, having an area of 20 sq. cm. The mean diameter is 25 cm. and there are 2000 turns in the winding. Required the average rates of change of flux density and total flux, with current, when the exciting current is brought from zero to values of 0.25, 1, 3 and 5 amperes respectively. Use the curve for wrought iron given on page 105. (*15 min.*)

6. In the case of problem 5, find the instantaneous rate of change of flux, when the current is passing through a value of one ampere. Also find the average rate between one and three amperes. (*5 min.*)

7. A conductor in the form of a loop is threaded by 10^6 lines of

force; the current is broken in $\frac{1}{100}$ second; required the average induced electromotive force set up, in volts. ($\frac{1}{2}$ min.)

8. A coil of 200 turns of wire is threaded by 100,000 lines of force. The exciting current is halved in $\frac{1}{100}$ second; required the induced e.m.f. If the original exciting current is 5 amperes, what is the inductance of the circuit? (*2 min.*)

9. The inductance of a certain dynamo is 40 henries; what will be the induced e.m.f. if the exciting current of 2 amperes is brought to zero in 0.025 second? (*1 min.*)

10. What is the average rate of change of current per second during a quarter of a cycle of a 60-period alternating current of 100 amperes (effective)? (*1 min.*)

11. If in problem 5 each one of the changes of current mentioned takes place in $\frac{1}{100}$ second, what will be the e.m.f. set up in each case? (*3 min.*)

12. If in problem 6 the current is changing at the rate of 50 amperes per second when it passes through one ampere, what e.m.f. will be induced at this instant? (*1 min.*)

13. With an exciting current of 7.5 amperes through 1000 turns the reluctance of a magnetic circuit is 0.1257. If the current increases by 2% of this value, the reluctance increases 1%. If this increase of current is at the rate of 15,000 amperes per second, required the e.m.f. induced. What is the average inductance during this increase? (*3 min.*)

14. The core of a 25-kv-a., 60-period transformer is 15×20 cm. and the primary winding has 500 turns. The density, corresponding to a magnetizing current of 0.2 ampere, is 5000. Required the average inductance for this current, and the induced e.m.f. if the current were reduced to zero at a rate of 100 amperes per second. (*3 min.*)

15. An electromagnet has 1200 turns; with 4.5 amperes the flux is 5×10^7, and with 2 amperes 3×10^7. What is the average inductance? If the density is such that between these limits the magnetization curve can be taken as a straight line, what will be the e.m.f. of inductance if the current change from 3 to 3.2 amperes in 0.1 second? (*3 min.*)

16. A circuit has 1000 turns, the area of the enclosed magnetic circuit is 20 sq. cm. With 4 amperes the density is 10,000 and with 9 amperes it is 14,000. Required the average value of L between 4 and 9 amperes. (*1 min.*)

17. An air magnetic circuit has 753 turns and is threaded by 646,000 maxwells when the exciting current is 8.4 amperes. If in 0.23 second the current is increased from this value to 97.3 amperes, what inductive e.m.f. will result? (*4 min.*)

18. A dynamo field has 7320 turns, is $9\frac{1}{4}$ inches in diameter and has a density of 16 kilogausses. If the exciting current is broken in 0.13 second and the density fall to a residual of 900 gausses, to what value will the e.m.f. at the terminals of the field circuit rise? Also if 2.6 seconds be allowed for the breaking of the field circuit? (*6 min.*)

19. A wrought-iron ring, with 2340 turns, an area of 0.98 sq. cm. and a cut (air gap) across it of $\frac{1}{4}$ inch, has 14.0 kilogausses for a current of 4.72 amperes, what is the average inductance? (*3 min.*)

20. In problem 19 what would be the inductance if the cut were increased to $\frac{1}{2}$ inch by forcing the ends apart? Also if the ends were forced together so as to make the air gap negligible? (*6 min.*)

21. A wrought-iron ring, 1.13 feet in inside diameter and 0.872 inch diameter of iron, has one layer of No. 30 double-cotton-covered magnet wire. If current enough is used to give a density of 8000 gausses, what will be the number of turns, the current and the average inductance? See table of magnet wire on page 104. (*5 min.*)

22. If in problem 21 the density is doubled, what will the current be and what will the inductance become? (*2 min.*)

23. A ring of cast iron 20 inches in mean diameter and made of 2-inch round iron is wound with 3250 turns. Find the mean value of L for 0.2, 0.5, 1 and 2 amperes and plot the curve of inductance with current. (*15 min.*)

24. Required the inductance of a winding of one layer of No. 18 double-cotton-covered magnet wire upon a wooden ring, 7.5 inches mean diameter and 0.763 inch diameter of cross-section. If the resistance be 0.375 ohm, what is the time constant? (*6 min.*)

25. A certain 100-kv-a. transformer for 5000 to 500-volt transformation has a maximum flux of 2.0×10^6 with a cross-section of 300 sq. cm. The secondary turns are 110 and the primary 1100, the effective exciting current is 0.333 ampere. Required the average inductance of each winding between maximum flux and zero flux. (*1 min.*)

26. The shunt field of a 110-volt dynamo has a resistance of 42 ohms and an inductance of 12 henries. If 100 volts be applied to the terminals, how long will it take the current to reach 0.95 of its maximum value? How long to reach 0.99? (*4 min.*)

27. A circuit has an inductance of 100 henries. Plot curves of current rise with an applied constant e.m.f. of 100 volts for the following resistances, 1, 10, 100 and 1000 ohms. Use different scales so as to bring the final current value the same in each case. (*30 min.*)

28. If the exciting current at 110 volts in problem 26 be broken in $\frac{1}{20}$ of a second and the current thereby reduced to zero, what e.m.f. will exist between the terminals? (*1 min.*)

29. Two coils, A and B, lie in parallel planes; 60% of the lines produced by one coil thread through the other. Five amperes through the coil A produces a flux of 5000 in A. If the current in A change from +6 to −6 amperes in 0.01 second, what will be the e.m.f. produced in coil B, if B have 1000 turns? What is the mutual inductance? (*3 min.*)

CHAPTER II

QUANTITY AND CAPACITY, CONDENSERS

1. A current of 5 amperes flows for one-half hour; how many coulombs are passed? To what e.m.f. would this raise a 20-microfarad condenser? A 50-microfarad condenser is charged to 2000 volts; how long would this condenser maintain a current of one ampere if closed through an outside circuit? (*2 min.*)

2. An electric motor takes 1 kilowatt at 200 volts. How many coulombs will it use in 2 hours? How many if the voltage be 500 and the power the same? (*2 min.*)

3. How many coulombs and how many watt-hours are represented by the charge in a 100-microfarad condenser on a 10,000-volt circuit? What will each of these become if the voltage is doubled? (*4 min.*)

4. To what voltage will 5 coulombs charge a 1-microfarad condenser? A 100-microfarad condenser? (*1 min.*)

5. How long would it take to charge a 10-microfarad condenser on a 50,000-volt circuit, if the average current were 2 amperes? How long to charge with the same current a 100-microfarad condenser on a 100-volt circuit? (*2 min.*)

6. What would be the capacity in microfarads of a condenser which would require 2000 volts to bring to a charge of 1 coulomb? ($\frac{1}{2}$ *min.*)

7. What capacity would be necessary to run a 25-watt tungsten lamp for 5 minutes at 100 volts? If a 2-microfarad condenser costs 90 cents what would the above cost? (*3 min.*)

8. What voltage would be required to charge a 50-microfarad condenser with one coulomb of electricity? (*1 min.*)

9. In 0.02 second the charge in a condenser changes from 0.283 to 0.231 coulomb; required the average current flowing. ($\frac{1}{2}$ *min.*)

10. A 10-microfarad condenser shows a drop in voltage from 3000 to 1500 in 0.03 second; required the average current. (*1 min.*)

11. Three condensers each having a capacity of 30 microfarads are in parallel. What is the combined capacity? What would be the capacity if they were in series? ($\frac{1}{2}$ *min.*)

12. Two condensers of 10 and 15 microfarads are in parallel; what is the combined capacity? What would it be if they were in series? (*1 min.*)

13. Two condensers have capacities of 1 and 20 microfarads; what are the combined capacities when they are in parallel, and when they are in series? (*1 min.*)

14. With the condensers of problem 13 in series on a 1000-volt circuit, what would be the voltage around each condenser? How could this arrangement be used in voltage measurement? (*3 min.*)

15. A 50-microfarad condenser charged to 2000 volts is connected to a non-inductive circuit of 100 ohms. Obtain, by approximate method, and plot a curve between terminal e.m.f. and time. Get points for 1, 2, 3, 4, 6 and 10 thousandths of a second; make approximations enough to locate the curves within 2%. (*10 min.*)

16. From the curves obtained in problem 15 determine the instantaneous value of the current at 0.0024 second after the beginning of the discharge. (*1 min.*)

17. The condenser of problem 15 is connected through the 100-ohm circuit to a 2000-volt e.m.f. Obtain the charge at the end of 1, 2, 3, 4, 6 and 10 thousandths of a second and plot the same. (*12 min.*)

18. Using the formula: Capacity $= \frac{KA}{36\,\pi d \times 10^5}$ microfarad, where A and d are area and distance between plates in centimeters and K is the inductivity of the dielectric, determine how many square meters of glass plates 3 mm. thick with copper foil on each side would have to be used to provide a 0.045-microfarad condenser for a 5-kw., 25,000-volt wireless sending outfit. Take the inductivity of the glass used as 6. Neglect the capacity between the adjacent plates. (*3 min.*)

19. As an alternative form of condenser for the above case, determine the number of metal plates 40 centimeters square, that would have to be immersed in petroleum with an inductivity of 2.2 and spaced 1 centimeter apart to give the same capacity. (*4 min.*)

CHAPTER III

ALTERNATORS AND WAVE FORMS

1. Required the frequency in periods per second of a current given by an 8-pole alternator running 900 r.p.m.; also of a 28-pole machine running 180 r.p.m. (*1 min.*)

2. A generator is to be driven by an engine running 120 r.p.m.; how many poles must it have to give a frequency of 60? A 40-period generator has 16 poles; at what speed does it run? (*1 min.*)

3. What is the speed of a two-pole turbo-generator for a 60-period system? Also for a 25-period system? (*1 min.*)

4. Find a number which when divided by the number of poles of any 60-cycle generator or motor will give the synchronous speed in r.p.m. Also for a 25-cycle machine. (*1 min.*)

5. Construct a table giving the speeds for machines from 2 to 36 poles for 60 and for 25 cycles. (*10 min.*)

6. What are the kilowatt capacities of a 100-kv-a. generator with currents lagging 30, 45 and 60 degrees? (*1 min.*)

7. An engine builder whose engine runs at 650 r.p.m. demands a 60-cycle alternator for direct coupling. What can be done for him? (*2 min.*)

8. By the rotation of a vector and taking its projections, plot the sine wave of current, $i = 100 \sin \alpha$. (*5 min.*)

9. By division into narrow strips and measuring the mean ordinates obtain the average ordinate for a half cycle. (*10 min.*)

10. Construct the curves of squared ordinates and by measurement of the surface obtain the mean ordinate, and hence the square root of the mean square ordinate. (*15 min.*)

11. Construct the following curves and explain which might be the wave form of an alternator and why:

$$e = 100 \sin \alpha + 20 \sin 2\alpha,$$
$$e = 100 \sin \alpha + 20 \sin (3\alpha - 30°). \qquad (40\ min.)$$

12. Find the effective value of a wave made up of straight lines rising from zero to a 100-volt maximum and falling to zero again,

and obtain the ratio of this to the average value. Compare this with the same ratio for the sine wave. (*10 min.*)

13. Find the effective value of the wave form $e = 100 \sin \alpha + 20 \sin (3\alpha - 30°)$ as constructed in problem 11, and obtain its ratio to the average value of the same curve. (*15 min.*)

CHAPTER IV

ALTERNATING CURRENT IN INDUCTIVE CIRCUITS

1. In a given circuit the resistance is 10, the inductance 0.01 and the frequency 60. Required the e.m.f. necessary to cause 2 amperes to flow. What current would flow if a direct-current e.m.f. of the same value were applied to the circuit? (*3 min.*)

2. In a certain circuit, $r = 1$, $L = 0.01$ and $\omega = 400$ (frequency $= 63.7$); required the current and angle of lag if 50 volts are applied. What would be the current if this e.m.f. were direct current? Give the equation for the instantaneous value of the current. (*4 min.*)

3. In a certain circuit r is 2 and L is 0.02 and a 100-volt alternating e.m.f. gives 10 amperes; required the frequency of this current; also the reactance and impedance of the circuit. (*3 min.*)

4. In a certain circuit r is 2 ohms, and with a 200-volt 50-period circuit 50 amperes flow; required the values of the inductance, reactance and impedance. (*3 min.*)

5. The exciting current of a 100-volt, $3\frac{1}{2}$-kw. shunt generator field is 2 amperes, and its inductance is 10 henries; required what this current would be if an equal 60-period e.m.f. were applied to it. Also if the alternating current were of 120 periods. (*7 min.*)

6. The primary circuit of a 2000-volt, 2-kw. transformer has a resistance of 20 ohms, and an inductance of 40 henries. What current will flow through this coil on a 60-period, 2000-volt circuit, the secondary circuit being open, and what will be the angle of lag. What current would flow with a direct current of equal e.m.f.? Give the equation for instantaneous current values. (*6 min.*)

7. A 10-ohm coil is placed upon a 100-volt circuit in which ω is 400; it is found that the current lags 30 degrees; required the current, the inductance and the reactance of the circuit. (*4 min.*)

8. In the circuit of problem 10 the e.m.f. is raised until 200 amperes flow, what will it become? (*2 min.*)

9. A current of 3000 amperes delivered by a 100-volt transformer with $\omega = 400$, has a power factor of 80%; required the resistance and reactance of the circuit. (*3 min.*)

10. If a milliammeter with inductance in series be used as a frequency meter, upon a circuit of constant e.m.f. of 120 volts, and if the resistance is negligible and the inductance is 10, what current will indicate a frequency of 60 periods? (*2 min.*)

11. Given E, 127; r, 40; I, 1.54; and the frequency, 115; required the reactance, inductance and angle of lag. (*6 min.*)

12. Given E, 1100; I, 6.54; r, 86; and the frequency, 115; required the reactance and inductance. (*6 min.*)

13. Given an impressed e.m.f. of 100; r, 5; and I, 12; determine the value of L and the induced e.m.f. if the frequency is 63. (*3 min.*)

14. Required the e.m.f. to send 10 amperes through a circuit with 3 ohms if the e.m.f. of inductance is 20. (*1 min.*)

15. Given for a coil of wire r, 40 and L, 0.05; if the frequency is 95.5, required the angle of lag as defined by the tangent and the e.m.f. necessary to send 10 amperes through. Construct the angle of lag. (*6 min.*)

16. An inductive circuit having a resistance of 2 ohms carries 10 amperes, maximum, and an inductive e.m.f. of 10 volts maximum is set up in the circuit. Construct the sine curves for active e.m.f. and induced e.m.f. and from these derive and construct the curve of impressed e.m.f. (*10 min.*)

17. A circuit of 5 ohms resistance carries 20 amperes maximum; an inductive e.m.f. of 30 volts is set up in the circuit. Construct the e.m.f. parallelogram for this case, and by revolution of this construct the sine curves for the active, induced and impressed e.m.f.'s. (*10 min.*)

18. Given for a circuit resistance 4 ohms, maximum current 20 amperes, maximum inductive e.m.f. 20 volts; construct e.m.f. curves, including the impressed e.m.f., and from these the parallelogram of e.m.f.'s. (*10 min.*)

19. Given an effective current of 20 amperes in a circuit whose resistance is 4 and reactance 2 ohms; plot the curves of active and induced e.m.f. and from them the curve of impressed e.m.f. Also construct the e.m.f. parallelogram which would generate these curves. (*10 min.*)

20. In a circuit of 10 ohms and 0.005 henry, what is the largest value that the frequency can have, without producing a decrease of more than 1% in the current which flows when the frequency is zero? (*5 min.*)

21. An instrument for use on a circuit with ω, 400 (frequency, 63.7) has r, 1000, and L, 1. What per cent increase of frequency would cause an error of 1%? (*7 min.*)

22. Given a laminated ring 30 cm. in circumference, 3 cm. in diameter of cross-section and having $\mu = 2000$, at a density of B = 6000; required the number of turns to give L = 0.1. (*4 min.*)

23. Given for an inductive circuit r, 5; L, 0.01; E, 75; and I, 11.8; required the frequency. (*4 min.*)

24. A solenoid of 800 turns, 1 meter long and 5 cm. in diameter, has r, 0.15 ohm; required the inductance and the current when a 10-volt, 75-period current is applied, and also the angle of lag. What would the current be if the same wire were wound non-inductively? If the frequency be doubled, what will be the current and the angle of lag? (*15 min.*)

25. Given for an inductive circuit r, 40.4; L, 0.101; frequency, 100; and I, 1.34; required the impedance, the e.m.f. and the angle of lag. (*7 min.*)

26. A circuit has 0.025 henry and a variable resistance. 115 volts having a periodicity of 58 is applied; construct the locus of the current vector, and show graphically that it is correct for two cases. (*5 min.*)

27. A circuit on a 100-volt system has a resistance of 5 ohms. Plot the locus of current with varying reactance. Note that the change in reactance may be due either to change in inductance or frequency, so that the same curve could be used for either. (*5 min.*)

28. A condenser of 50 microfarads capacity is connected to a 60-period, 110-volt circuit. What charging current will flow? What will it become on 1100 volts. What will be the ratio of volt-amperes in the two cases? (*4 min.*)

29. If the condenser of problem 28 is used on a 1200-period, 1100-volt circuit, what will the charging current be? What will be the capacity reactance? (*3 min.*)

30. A 25-period, 100,000-volt, 110-mile transmission line has an equivalent capacity of 0.01 microfarad per mile. What will be the charging current and the charging kilovolt-amperes? What is the capacity reactance? (*3 min.*)

31. A 100-microfarad condenser is connected to an alternating-current generator having ω, 400, through a line of negligible resistance; the maximum current is 8. Plot sine curves of current

and condenser and generator e.m.f.'s in their proper phase relation. Construct a vector diagram for these three curves. (*10 min.*)

32. The e.m.f. curve, $e = 100 \sin \alpha + 20 \sin (3\alpha - 30°)$, constructed in problem 11, Chapter III, has $\omega = 400$ for its fundamental, and is applied to a circuit having an inductance of 0.05 henry and a resistance of 2 ohms. Plot the e.m.f. and the current curve in their proper phase relation. (*30 min.*)

33. The same e.m.f. as in problem 32 is applied to a 100-microfarad condenser. Plot the curves of e.m.f. and current in their proper relation. (*25 min.*)

CHAPTER V

INDUCTIVE CIRCUITS IN SERIES AND PARALLEL

(Solve all problems graphically and give results in numbers. Angles may be defined by their tangents.)

1. Two circuits having resistances of 2 and 10 ohms respectively and $\frac{1}{10}$ and $\frac{1}{100}$ henries are in series on a circuit having ω, 300; find the e.m.f. around each of these and across the outside terminals with 200 amperes flowing. What is the frequency? (*5 min.*)

2. An induction coil is to be used for cutting down the light of a 100-volt lamp; the voltage is to be reduced to 50, with which the current through the lamp is 0.2 ampere. If the coil have 10 ohms resistance, determine what will be the e.m.f. induced in it, and what will be its terminal e.m.f. What per cent of the energy used will be consumed in the coil? What is the power factor? (*4 min.*)

3. Two inductive circuits in series are designated by r_1, r_2, x_1, x_2, E_1, E_2, E and I. In general, if five of these are given the other three can be determined graphically from the triangle diagram. Draw and letter this diagram and then state briefly but completely the geometrical construction for the cases where the following are the unknown quantities: (a) r_1, r_2, x_2; (b) r_2, x_2, E; (c) r_2, x_2, I; (d) x_2, E_1, E_2; (e) x_2, E, I; (f) E_1, E_2, I. (*30 min.*)

4. Given the resistances and reactances of three circuits in series, and the line e.m.f. Show how to determine the current and the e.m.f. for each circuit. (*5 min.*)

5. Given two circuits having r_1, 5; L_1, 0.01; r_2, 20; and L_2, 0.02; if an alternating current of 500 amperes with ω, 600, be put through these two circuits in series, what e.m.f. must be used and what will be the drop and lag for each? (*8 min.*)

6. Three circuits, A, B and C, are in series and have respectively 0.1, 0.01 and 0 henry and 5, 15 and 12 ohms. With 5 amperes at 60 periods find the drop around A and B, B and C, and A, B and C. (*7 min.*)

7. Circuits A, B and C in series have inductances of 1.2, 0 and 0.3 and resistances of 0, 50 and 100; also a 100-period current gives

a drop of 1000 volts around A; required the drops around B and C in series and A, B and C in series. (*7 min.*)

8. Two circuits in series have resistances of 10 ohms each, one has 10 ohms reactance and the e.m.f. across the other is 15; with 1 ampere flowing, find the impressed e.m.f. and the reactance of the other circuit. (*5 min.*)

9. Two circuits in series have reactances of 2 and 4 ohms, the first has 3 ohms resistance; if 50 amperes flow when the circuits are placed on a 400-volt circuit, required the value of the other resistances. (*5 min.*)

10. Given two circuits in series, one of 10 ohms resistance and the other of 0.1 henry inductance; required the current if E be 1000 and ω, 600. Also if the first circuit be cut out. (*4 min.*)

11. The secondary of a transformer and the load it supplies with current are in series. The e.m.f. impressed on the secondary is 100 and its resistance and reactance are 0.02 and 0.085 ohms. The current is 150 amperes, lagging 45 degrees behind the impressed e.m.f. Required the voltage on the load and its power factor. (*5 min.*)

12. For three circuits in series the resistances are 100, 75 and 30 and the inductances 1, 0.3 and 0; the frequency is 60; required the lag for each circuit and for the system; also the power factor for the system. (*10 min.*)

13. A 50-volt incandescent lamp taking $\frac{1}{2}$ ampere is placed on a 100-volt circuit; what must be the value of L in a choke coil placed in series with this lamp to give the right voltage, if the resistance of the coil be negligible and if the frequency be 100? What will be the lag, the power factor and the efficiency of the combination? (*5 min.*)

14. The resistances of three circuits in series are 12, 8 and 5 ohms; the inductances of the first two are 0.1 and 0.15, and the tangent of the angle of lag of the third is $\frac{1}{4}$, ω is 200. With 20 amperes flowing through the circuit, find the e.m.f. between the terminals. (*5 min.*)

15. A choke coil to turn down a 55-watt, 110-volt lamp, reducing the pressure to 50 and 25 volts, is to be designed. What must be the inductive e.m.f.'s, neglecting the resistances of the coil? Required also the power factors. (*7 min.*)

16. A circuit having r, 5, and x, 2, is fed by a transmission line of 1 ohm resistance. With a generator e.m.f. of 1000 volts, what

will be the e.m.f. on this circuit? What per cent will the drop in the line, from no load to full load be, of this e.m.f.? (*4 min.*)

17. A machine takes 30 volts and 12 amperes; required the inductive e.m.f. of a choke coil to be placed in series with it on a 100-volt circuit, if the resistance of the choke coil and the inductance of the machine be negligible. (*3 min.*)

18. A soldering iron built for 50 volts and 3 amperes is to be used on a 100-volt, 60-period circuit, with a choke coil. If the resistance of the choke coil is 1 ohm, required the e.m.f. around the choke coil, the inductive e.m.f. and the inductance. (*4 min.*)

19. Required the inductive e.m.f. to be given by a 0.2-ohm choke coil so that the e.m.f. of a circuit may be cut from 100 to 40 volts, for a 10-ampere current. What is the power factor and the efficiency? (*4 min.*)

20. Required the e.m.f. around a 3-ohm choke coil to be used in series with a 50-volt, 25-candle-power lamp, taking 1 watt per candle-power for use on a 110-volt circuit. Required also the efficiency. (*4 min.*)

21. A motor takes 50 amperes, lagging 30 degrees. It is fed through a circuit of 1 ohm resistance; what must be the generator e.m.f. to give 1000 volts at the motor? What is the drop at the motor terminals from no load to full load? (*3 min.*)

22. Two circuits are connected in series upon a 200-volt e.m.f. The resistance and reactance of the first are 0.50 and 0.75 ohms, and a current of 20 amperes lagging 30 degrees behind the e.m.f. of the second circuit is flowing; required the e.m.f.'s on both circuits. (This problem is used on transformer work. The first circuit is the transformer secondary, the second the load.) (*4 min.*)

23. The secondary coil of a transformer and the circuit which it supplies are in series. The e.m.f. impressed upon the secondary is 200 volts, and its resistance and reactance are 0.2 and 0.5 ohms. The current is 50 amperes, and lags 30 degrees behind the terminal e.m.f. of the transformer. Required the voltage on the load and the impedance drop in the secondary. (*3 min.*)

24. An induction motor taking 5000 kilowatts at 10,000 volts and 85% power factor is supplied through a line having a resistance of 1.2 ohms, and a reactance of 0.3 ohm. What must be the generator e.m.f.; also the drop in volts at the motor from no load to full load; and the regulation, that is, the per cent which the above drop is of the full-load voltage. (*6 min.*)

25. A 7-ampere series-arc lighting system is operated upon a 6600-volt circuit. The volts per lamp are 75 and the power factor of the lamps is 83%. The current is maintained constant by a 75-light inductive regulator having 30 ohms resistance. What will be the voltage across its terminals when the full load of lamps is on; also for 40 lights, and for 5 lights? (*10 min.*)

26. Construct the diagram for a rotary converter, reactance coil and line in series. The converter is taking 120 amperes, lagging 30 degrees, and its terminal e.m.f. is 1000 volts. The resistances of the coil and line are 0.4 and 0.8 ohms, and their reactances 1.5 and 0.2 ohms. Find the generator e.m.f., the power factor of the system and the voltage at the end of the line. (*6 min.*)

27. Find graphically the sum of the following currents and the tangent of the lag of the resultant:

30 amperes, lagging 15 degrees,
20 amperes, lagging 45 degrees,
10 amperes, leading 30 degrees,
5 amperes, in phase. (*4 min.*)

28. An induction motor taking 50 amperes and with a power factor of 0.7 has in parallel with it 200 $\frac{1}{2}$-ampere lamps in parallel. Find the total current. (*3 min.*)

29. At a certain point in a circuit there are 50 amperes flowing with a power factor of 86.6%. 20 amperes is then taken off for a group of incandescent lamps while the balance passes on to an induction motor. What current does the motor take and at what power factor? (*3 min.*)

30. Two parallel circuits on a 2200-volt system have resistances of 5 and 10 and reactances of 5 and 20; required the current and lag. (*7 min.*)

31. Fifteen 50-watt, 100-volt lamps are in parallel on a 100-volt system and in parallel with a circuit of 5 ohms and 0.005 henry; the frequency is 120. What is the current, the angle of lag and the power factor? (*8 min.*)

32. Ten enclosed arc lamps in parallel, each taking 6 amperes and 70 volts active e.m.f., and with choke coils in series, are in parallel with 250, 110-volt, 0.55-ampere incandescent lamps. What will be the total current? (*6 min.*)

33. On a 10-ampere circuit is to be placed a group of five 1-ampere, 50-volt lamps in parallel. To by-pass the remainder of the current a choke coil (resistance negligible) is to be used in parallel with the lamps. For what current must this coil be designed? (*3 min.*)

34. Two circuits in parallel have respectively $r_1 = 12$; $\tan \phi_1 = 1.25$; $r_2 = 30$; and $L_2 = 0.015$. What will be the angle of lag of the resultant current and what will be its value if E be 117 volts and ω be 500? (*8 min.*)

35. Two parallel circuits on a 5000-volt system have resistances of 20 and 50; also the power factor of the first is 0.447, and a current of 40 amperes flows in the second circuit; required the reactance of this circuit and the total combined current. (*8 min.*)

36. Two motors are running in parallel on a 500-volt system. One has an equivalent resistance of 5 and a power factor of 89.4%. The combined current is 110 amperes and lags 30 degrees. Find the current in each motor and the power factor of the second motor. (*5 min.*)

37. If the two circuits of problem 1 are placed in parallel on a 220-volt circuit, and the first circuit takes 25 amperes, determine the frequency and the current in the other circuit. (*7 min.*)

38. Using the notation of problem 3, but with the circuits in parallel and carrying currents I_1 and I_2, draw the diagram and state the solution for six cases as follows: To find x_1, x_2, I; r_2, x_1, I; r_2, x_1, x_2; E, I_1, I_2; E, I, I_2; E, x_1, x_2. (*20 min.*)

39. An induction motor taking 10 amperes with a power factor of 86.6% is placed on the same line with 30 incandescent lamps, in parallel, each taking $\frac{1}{2}$ ampere; find the current in the line. Required also the power factor. (*3 min.*)

40. A projection lamp taking 15 amperes at 40 volts and with a power factor of 85% is to be used in parallel with a load of lamps on a 110-volt system. Compare the currents in the feeder with a transformer and with a choke coil used to reduce the e.m.f. (a) With 200 $\frac{1}{2}$-ampere lamps in parallel. (b) With 20 $\frac{1}{2}$-ampere lamps in parallel. Which would you use, transformer or coil? (*7 min.*)

41. On a certain circuit are an induction motor, synchronous converter and a load of incandescent lamps. The motor has equivalent resistance and inductance of 5 and 0.01, the converter 3 and 0.015, while the combined resistance of the lamps is 6.25.

If the frequency is 60 and the motor is taking 16 amperes, required the currents in the other two circuits, the whole current and its power factor and the necessary e.m.f. (*10 min.*)

42. Two parallel circuits have resistances of 20 and 30 ohms and reactances of 10 and 40; find the e.m.f. necessary to give a combined current of 100 and how this current divides between the circuits. (*8 min.*)

43. The load on a transformer is made up of 500, 200-ohm incandescent lamps and an induction motor circuit having an equivalent resistance of 0.25 and a power factor of 70.7%. The current is 500. Find the e.m.f., the current in each circuit and the power factor of the system. (*9 min.*)

44. The resistance of two circuits in parallel are 16 and 20 ohms and their inductances 0.08 and 0.12 henries; the frequency is 80; required the e.m.f. necessary for a total current of 10 amperes. (*9 min.*)

45. Three parallel inductive circuits of 3 ohms resistance each have power factors of 0.2, 0.4 and 1. The total current is 200 amperes. Required the e.m.f. and power factor of the current. (*4 min.*)

46. Two induction motors are run on the same circuit and take together 400 amperes with a power factor of 0.75; one motor has a power factor of 0.70 and an equivalent resistance of 0.8; the current taken by the other is 250. Find the e.m.f. and the other current; also the other power factor. (*5 min.*)

47. If the 3 circuits of problem 6 are placed in parallel and the combined current is 50 amperes, find the e.m.f. and the power factor of the system. (*8 min.*)

48. Four parallel circuits have resistances of 20, 10, x and 1, and inductances of 0, 0.025, 0.12 and y; the e.m.f. is 200, periodicity, 90, and the currents in the third and fourth circuits, 2.6 and 1.6. Find the currents in the first and second, the total current and its lag, and the equivalent resistance and inductance for the whole circuit. (*10 min.*)

49. Two parallel circuits have 0.2 and 0.03 henries and 0 and 10 ohms respectively; a circuit in series with them has 0.05 henry and 8 ohms; the current through the 10-ohm circuit is 3 amperes at 60 periods; required the e.m.f. around each circuit and around the whole; also the two unknown currents and the lag for the system as a whole. (*10 min.*)

50. Required the inductive e.m.f. of a choke coil to be placed in series with a projection arc lamp taking 15 amperes at 35 volts when used on a 110-volt circuit, the resistance of the coil being $\frac{1}{2}$ ohm. If 60 110-volt, $\frac{1}{4}$-ampere lamps are in parallel with the above, and with each other, what will be the total current? (*6 min.*)

51. A 5-ampere arc lamp is to be used on a 7.5-ampere constant-current line. Its power factor is 86.6% and its terminal e.m.f. 72 volts. A choke coil with a resistance of 2 ohms is to by-pass the remaining current. Construct the diagram and determine the current in the coil and the power factor of the combination. (*7 min.*)

52. It is required to measure the exciting or no-load current of a $\frac{1}{2}$-kw. transformer on a 120-volt circuit. In order to adjust the voltage a voltmeter with 800 ohms resistance and negligible reactance is in parallel with the transformer so that the ammeter reads its current also. The total current is 0.45 ampere with a power factor of 79%. What is the exciting current and its power factor? (*3 min.*)

CHAPTER VI

CAPACITY AND INDUCTIVE CIRCUITS, RESONANCE

1. A 200-microfarad condenser is connected through a resistance of 50 ohms to a 100-volt circuit having $\omega = 400$ (frequency 63.7). Construct the triangle and determine the current and power factor. (*2 min.*)

2. The same condenser is connected through a resistance of 2 ohms to a 1000-volt circuit of the same frequency. Construct the triangle and find the current and power factor. (*2 min.*)

3. Two circuits have resistances of 5 and 20 ohms, and their capacities are respectively 100 microfarads and infinity. If they are in series on a 200-volt circuit with $\omega = 400$, find the current and power factor. (*2 min.*)

4. A circuit with 15 ohms resistance and 0.02 henry inductance connects a 500-volt alternator to a 120-microfarad condenser; ω is 500; find the current and the angle of lag or lead. (*4 min.*)

5. A condenser of 12.5 microfarads is fed through a resistance of 100; the maximum current is 1 and ω is 400. Plot sine curves of current and condenser e.m.f., and hence determine the curve of impressed e.m.f. Construct the vector parallelogram for these three curves. (*10 min.*)

6. In problem 5 replace the resistance with an equal impedance in which the power factor is 0.707. Plot the curves of active, induced and condenser e.m.f. and from them determine the impressed e.m.f. curve. (*15 min.*)

7. In problem 5 what reactance would have to be inserted to bring the current into phase with the impressed e.m.f.? Also for the circuits of problems 4 and 6 of Chapter V? (*2 min.*)

8. Given for a circuit: $E = 100 \sin \theta$; $R = 2$; $L = 0.01$; $\omega = 600$; capacity $= 0.001$. Find the equation for the instantaneous currents. (*4 min.*)

9. An over-excited synchronous motor takes 130 amperes with a power factor of 50%. What will be the e.m.f. at its terminals

when connected through a line of 1.1 ohms resistance to a 400-volt generator? (*3 min.*)

Note. — An over-excited synchronous motor or converter acts like a circuit with resistance and capacity; that is, it has a leading current.

10. Upon a circuit having $\omega = 400$ (frequency = 63.7), two circuits in series have respectively 19 ohms and 0.007 henry, and 5 ohms and 125 microfarads, what e.m.f. will be necessary to send 11 amperes through the combination? What change in frequency would give unity power factor or resonance? (*5 min.*)

11. Upon the same circuit as above, two circuits are connected in series, one of which has 7.2 ohms and 0.22 henry, and the other 5 ohms and 32 microfarads. What line e.m.f. will give 1000 volts on the condenser? What will be the current and the voltage on the inductive circuit? (*5 min.*)

12. In problem 11 what capacity would be needed to give a leading current with 90% power factor? Also to give unity power factor or resonance? Check the graphical solution by the formula for series resonance. (*4 min.*)

13. An induction coil has a resistance of 25 ohms, and when placed on a 1000-volt circuit with $\omega = 400$, passes 2 amperes. What must be the capacity of a condenser in series with this circuit to give resonance? If the same line voltage were maintained, what current would flow, and what would be the voltage around the induction coil and also that at the terminals of the condenser? Give the graphical solution and check analytically. (*6 min.*)

14. Construct the sine curves of e.m.f. around the condenser and the inductance coil in problem 13, and from them derive the curve of impressed e.m.f. Compare the result with that obtained in problem 13. (*15 min.*)

15. In problem 10, if the circuits are placed in parallel, find the necessary e.m.f. (*6 min.*)

16. Three circuits in parallel have respectively 8, 12 and 3 ohms, 0, 0.06 and 0 henries and 200, infinity and 300 microfarads capacity; ω is 500. If 200 volts are applied, required the current, the phase angle and the power factor. (*10 min.*)

17. Two circuits are in parallel on a 100-volt, 60-period system; one has 10 ohms resistance and 3 ohms reactance; the other has resistance and 60-degree lead. Determine what its capacity and

resistance must be in order that the current shall be brought into phase with the e.m.f. so as to produce resonance. (*6 min.*)

18. In problem 17 if the resistance of the condenser circuit be eliminated, what will the necessary capacity become? (*2 min.*)

19. In problem 18 if the resistance in the first circuit be reduced to 2, what will the necessary capacity become? (*4 min.*)

20. Given an enclosed arc lamp taking 75 volts at the arc and 7 amperes, and used on a 100-volt circuit; required the capacity that would have to be used in parallel to make the power factor equal to 1; also the current under these conditions. (*4 min.*)

21. An induction-motor current of 25 amperes has a power factor of 80%; the e.m.f. is 947 and the frequency 60. If the wattless current required were to be supplied by a condenser in parallel, its circuit having no resistance, what would be its capacity? (*3 min.*)

Note. — If the wattless current is supplied by a condenser, the power factor becomes unity.

22. If, in the above, the frequency were doubled, what would be the capacity needed? Also if the e.m.f. were halved with the frequency at 60? (*1 min.*)

23. A generator giving 4000 volts feeds a 5-microfarad condenser through an inductive circuit in which r is 10, L is 1.25 and ω is 400. Required the e.m.f. on the condenser. (*2 min.*)

24. 100 volts at 96 periods is applied to a system consisting of two parallel circuits having respectively 0.008 and 0.02 henry, 0 and 10 ohms and capacities of 125 microfarads and infinity respectively. In series with these is another circuit having 0.005 henry and 5 ohms; required the currents, unknown e.m.f.'s and lag for the system. (*12 min.*)

25. What must be the capacity of a condenser to be placed in parallel with the inductance coil of problem 13 in order to give resonance on a circuit with $\omega = 400$, and what line current would have to be supplied to obtain 40 amperes maximum through the inductance coil? What would be the maximum impressed e.m.f.? Check the results as obtained graphically by the proper formula. (*8 min.*)

26. Construct the sine curves which are represented by the vectors of problem 25 and prove the numerical relation of their ordinates for three points. (*20 min.*)

27. Given a circuit of 6.52 ohms resistance and 80 microfarads capacity, to which an e.m.f. of 130 periods and 400 volts is applied. Find the value of L which makes the current a maximum, and then the values of the current and lag or lead for the following values of L: 0, 0.01, 0.03, 0.04. Plot these in terms of L. (*30 min.*)

CHAPTER VII

SINGLE-PHASE POWER, WATTMETERS

1. Required the power consumed in each of the following cases:
50 amperes at 1000 volts and the power factor 0.80;
30 amperes at 400 volts with a 30-degree lag;
1000 volts at 60 periods on a circuit of 10 ohms and 0.02 henry. (*3 min.*)

2. A single-phase motor takes 49 kilowatts at 350 volts with a lag of 30 degrees; what will be the current and how much larger must the conductors be than for a direct current of the same voltage? (*2 min.*)

3. A 110-volt generator is rated at 120 kilovolt-amperes or 120 kilowatts on an inductionless load. What would be its rating on the following loads: (a) A power factor of 0.9; (b) a power factor of 0.7; (c) current lagging 30 degrees; (d) current leading 60 degrees. (*1 min.*)

4. The station voltmeter reads 1100, the ammeter reads 150 and the wattmeter reads 120 kilowatts; required the power factor of the system and the lag; also if the generator is fully loaded, what would be its kilowatt capacity at unity power factor. (*2 min.*)

5. A motor is taking 100 amperes (maximum) at 250 volts and with a lag of 30 degrees. Plot sine curves of e.m.f. and current and by multiplication of the ordinates derive and plot a curve of instantaneous power values. Integrate this curve (measure its area) and thus check the formula for power in an inductive circuit. (*20 min.*)

6. A motor circuit connected to a 100-volt alternating-current system is taking 25 amperes; the wattmeter reads 1.8 kilowatts; plot curves of e.m.f. (sine), current and, derived from these, watts, and check by integrating (measuring area) the watt curve. Take 1 large division equal to 30 degrees. (*20 min.*)

7. An inductance coil on a 500-volt, maximum, circuit has r, 5, and takes 10 amperes, ω is 400; plot the e.m.f. current and hence

the power curves, and find from them the power consumption. What are the power and wattless components of the current? Take one large division of the paper equal to 30 degrees. (*20 min.*)

8. Plot the curves and prove graphically, that is by measurement of area, that for the following case the watts equal IE cos Φ; maximum current, 126; maximum e.m.f., 140; lag, 36 degrees. Take one large division equal to 30 degrees. Where is the axis of the power curve relative to the axis of the e.m.f. curve? (*20 min.*)

9. A lamp and an induction coil are in series on a 120-volt system. The coil cuts down the voltage on the lamp to 70 at which it takes 0.15 ampere. The resistance of the coil is 50 ohms. Plot curves of instantaneous power values for the lamp, the coil and the combined load. (*30 min.*)

10. Draw a sine curve for an e.m.f. of 100 volts maximum, and for a current of 50 amperes with a power factor of 70.7%. From these plot the power curve. Repeat for the same current with a power factor of 0.5, and with zero power factor. (*40 min.*)

11. The cost of a certain 10,000-kilovolt-ampere power-plant complete is $80.00 per kilovolt-ampere. If the current supplied by this plant lags 30 degrees what will be the available output in kilowatts, and what is the decrease in the value of the plant as compared with the same plant at unity power factor? (*1 min.*)

12. 10,000 kilowatts are transmitted 100 miles at 80,000 volts over a line which has a resistance of 64 ohms. The power factor is 70%. If the power costs the power company 0.6 cents per kilowatt-hour and is used 10 hours a day for 300 days in the year, what would be the annual saving on copper loss if the power factor could be increased to unity? (*3 min.*)

13. Separating the two coils of a dynamometer ammeter and sending two currents differing in phase through them, the instrument reads 50.3. Ammeters in these two circuits read 7.35 and 11.47 amperes; what is the phase angle between the currents? (*2 min.*)

14. Required the maximum inductance that the shunt coil of a wattmeter can have if its resistance is 1500, in order that the error with a 100-period current shall not exceed $\frac{1}{2}$ of 1%, the maximum lag in the circuit to be measured being 45 degrees. (*2 min.*)

15. A wattmeter is to measure power in a circuit having a maximum angle of lag of 36 degrees; the periodicity is 60, and the resistance of the wattmeter shunt is 1000 ohms. How small must the value of L be in the wattmeter in order to get the results correct to within $\frac{1}{2}$ of 1%? The same problem, but with an angle of lag of 60 degrees. *(6 min.)*

CHAPTER VIII

POLYPHASE SYSTEMS AND POWER

1. A 2-phase, 3-wire system carries 30 amperes in each outside wire; what will be the current in the common return? ($\frac{1}{2}$ *min.*)

2. A 2-phase, 3-wire system is supplying 100 kilowatts at 500 volts and with 80% power factor; what will be the current in the third wire? What is the e.m.f. between the outside wires? (*2 min.*)

3. A 3-phase, Y-connected system has 4000 volts between wires. The neutral point is grounded. For what voltage must the insulation of the windings be designed? ($\frac{1}{2}$ *min.*)

4. A 3-phase, Y-connected system with a fourth or neutral wire is designed to use 110-volt lamps between the neutral and the outsides; what will be the e.m.f. between the three lines? ($\frac{1}{2}$ *min.*)

5. A 3-phase, delta-connected system carries currents of 50 amperes in the delta connections; what is the current in the lines? ($\frac{1}{2}$ *min.*)

6. With 300 amperes in the line of a delta-connected, 3-phase system, what current will flow in the mesh? ($\frac{1}{2}$ *min.*)

7. A 2-phase, 3-wire system is out of balance; the currents are 100 and 90 amperes, with an angle of 85 degrees between them. What is the current in the third wire? (*2 min.*)

8. The currents in an unbalanced delta-connected 3-phase system are 80, 90 and 100 amperes; what are the line currents and what are their phase relations (instead of 120 degrees)? Solve graphically. (*5 min.*)

9. The currents in the lines of a mesh-connected, 4-phase system are 400 amperes; what will be the currents in the meshes? With 1000 volts between adjacent lines, what will be the e.m.f. between opposite ones? (*1 min.*)

10. In the balanced 2-phase, 3-wire system of problem 2, the series coil of a wattmeter is put in the third wire while the pressure coil is across the outside. What will the instrument read and why? (*2 min.*)

11. By the revolution of a vector diagram construct the three-

current curves of a 100-ampere, 3-phase, Y-connected generator; also draw circuit diagrams showing the values and directions of the instantaneous currents in each circuit for $\alpha = 0°$, $30°$, $45°$, $60°$ and $90°$ and observe that the sum of the currents is zero in each case. (Hand in the vector diagram.) (*10 min.*)

12. Let the armature of the last problem be delta-connected with 100 amperes in the outside circuits; construct the vector diagram for the armature and line currents and by its revolution the sine curves for all the currents. Use the conventions that currents are positive in the mesh when counterclockwise and in the line when directed away from the junctions. Draw the five-circuit diagrams as in problem 11. (Hand in the vector diagrams.) (*20 min.*)

13. A 100-volt, delta-connected, three-phase system has in each branch resistance and reactance as follows: circuit (a), 3 and 3 ohms; circuit (b), 6 and 0 ohms; circuit (c), 1 and 5 ohms. Construct the diagram and determine the currents in the meshes and leads. (*10 min.*)

14. A 200-volt, delta-connected system has currents of 27, 43 and 18 with power factors of 100, 86.6 and 50%. Determine the currents in the leads and their phase relations (tangents) to the e.m.f.'s. (*10 min.*)

15. Each circuit of a 120-volt, Y-connected, 3-phase system has a resistance of 3 and a reactance of 6 ohms. Construct the diagram and determine the line currents and their power factors. (*8 min.*)

16. The three circuits of a 150-volt, Y-connected system are made up of groups of incandescent lamps having resistances respectively of 5, 8 and 10 ohms. Determine the current in each lead and the voltage to neutral around each circuit. (*15 min.*)

17. The three circuits of problem 13 are connected Y instead of delta; required the current and voltage of each and the phase angles (tangents) between the currents and line e.m.f.'s. (*20 min.*)

18. If in problem 16 a fourth, or neutral, wire is used, what will be the current in each of the four lines? (*4 min.*)

19. If in problem 17 a fourth wire is used, what will be the current in each of the four lines? (*8 min.*)

20. A two-phase, three-wire system takes 200 amperes, with a power factor of 86.6 in each phase, from a 100-volt generator and is supplied through lines, each of which has a resistance of 0.1 ohm.

What will be the voltage on each circuit and the phase angle (tangent) between it and the current? Note the effect of the common return in unbalancing the circuit. (*8 min.*)

21. A 4-wire, 3-phase system is supplying 150 amperes at unity power factor to synchronous motors connected delta, and 85 amperes each to three groups of incandescent lamps connected to the fourth wire. Find the current in each wire and the motor voltage if the lamps are for 125 volts. (*8 min.*)

22. A 3-phase, delta-connected system has 5 ohms non-inductive resistance in each mesh circuit. There are also 3 ohms in each main circuit outside of the delta. With 110 volts applied to the system, what will be the current in each circuit and the e.m.f. around the delta? (*6 min.*)

23. Same as problem 22, except that 2 ohms reactance is added to each of the mesh circuits. (*8 min.*)

24. Same as problem 23, except that 2 ohms reactance is added to each of the main circuits. (*8 min.*)

25. Given a ring-wound armature placed in a 2-pole field and tapped at 0, 90, 120, 180, 240 and 270 degrees. With 250 volts across opposite brushes, required the voltage across adjacent brushes (90 degrees apart) of 2-phase and across the 3-phase lines. If the generator is to give 100 kilowatts, what will be the current in the armature conductors for the single, 2-phase and 3-phase? Also what in the line? (*8 min.*)

26. If the armature of problem 25 is wound with 2 flat wires 50×400 mils and 600 circular mils per ampere be allowed, what would be the capacity as single, 2 and 3-phase generators? (*6 min.*)

27. Find the wire area and the B. & S. size for the lines to transmit 430 kilowatts at 22,000 volts, single-phase, 3-phase and 2-phase, 4-wire and 3-wire. Using the B. & S. numbers required, at 20 cents per pound, find the cost per mile of circuit in each case. Take 1200 circular mils per ampere as giving a satisfactory drop. (*15 min.*)

28. Given a 3-phase motor with 400 volts between the lines, power factor of 85%, efficiency of 80% and with 10 horse-power delivered; required the current in the lines and also in the conductors of the delta-wound armature. (*3 min.*)

29. Two wattmeters are placed in the outside wires of a balanced 2-phase, 3-wire system feeding two similar non-inductive

circuits with 100 volts; when normally connected, each of the instruments indicates 500 watts, but when the shunt coils are interchanged, each reads 50 watts. Draw a diagram to represent this case and find the currents. (*5 min.*)

30. The two wattmeters on a 2-phase system indicate 1500 and 200 watts; the e.m.f.'s are both 100 volts and are 90 degrees apart; the currents are 18 and 3 amperes. Draw a diagram for the case and determine the lags (tangents) of the currents. (*7 min.*)

31. A 2-phase, 3-wire system with e.m.f.'s of 400 volts, 90 degrees apart has currents of 25 amperes in each phase lagging 30 degrees; what total power would the wattmeter readings show with the two wattmeters placed normally, and also with their series coils both in the common wire; solve graphically. (*8 min.*)

32. In problem 31, if one current were 30 amperes, what would the sums of the wattmeter readings become? (*10 min.*)

33. Three wattmeters connected in the delta circuits of a 3-phase system show 1120, 1540 and 1780 watts, respectively, the voltages are each 440 and are 120 degrees apart, the currents are 3.2, 4.5 and 6.3 amperes. Construct the diagram for this case including the line currents and give the total power and the power factor of each circuit. (*12 min.*)

34. Three wattmeters are used with the voltage coils across the circuits to measure the power in a 220-volt, 3-phase, Y-connected system. Each reads 1250 watts and power factor meters show 75% power factor. Construct the diagram for the case and find the line currents and the total power. (*7 min.*)

35. The currents in the three leads of a 500-volt balanced delta-connected, 3-phase system are each 173.2 amperes; the readings of the two wattmeters properly connected to measure the power of the system are each 75 kilowatts. What is the power factor of the system? Prove by means of a vector diagram. (*6 min.*)

36. With the same system as in problem 35, except that the wattmeters read 75 and 0 kilowatts, draw the diagram and determine the power factor. (*5 min.*)

37. Repeat problem 35, except that the wattmeter readings are plus 60 and minus 24 kilowatts. (*7 min.*)

38. What would be the readings of two wattmeters with their series coils in the same branches as circuits (a) and (b) of problem 17? (*10 min.*)

39. Repeat problem 38, except that the wattmeters are in the same branches as circuits (b) and (c). (*10 min.*)

40. Determine graphically what the readings on two wattmeters placed with their series coils in the leads between the first and second and between the second and third circuits of problem 33 would be. (*10 min.*)

41. A 3-phase, delta-connected alternator is giving 750 amperes for one phase only. What will be the current in each circuit of the alternator? Also what if a 200-ampere, single-phase circuit is connected to each of two phases? (*5 min.*)

42. Show what, on a basis of heating, will be the capacity of a 100-kilovolt-ampere, 3-phase delta-connected alternator when run single phase. Also if the alternator is Y-connected. (*2 min.*)

43. Repeat problem 42, except that the load is to be two equal single-phase circuits, one on each of two phases. (*3 min.*)

CHAPTER IX

TRANSFORMERS, GENERAL

1. A 10 to 1 transformer has the same length of turn and current density in both coils. The secondary resistance is 0.01 and the secondary turns are 80; required the primary resistance. With 110 volts and 2.2 kilowatts, given by the secondary, required the primary e.m.f. and current (neglect drop and magnetizing current). (*1 min.*)

2. The resistance of the two coils of a transformer marked for 110-volts secondary are 0.3 and 0.012; if the current density and length of turn are the same, for what primary voltage is the transformer designed? (*1 min.*)

3. A 500-kv-a., 40,000-volt transformer with 2000-volts secondary, has 420 secondary turns; what would be the area of this secondary conductor in square inches allowing 2000 circular mils per ampere? Also the resistance if the mean length of a turn is 9.5 feet and the resistance of a circular-mil-foot be taken as 12.5? Also required the primary turns, current and resistances with same current density and length of turn in the two coils. (*5 min.*)

4. In problem 2, if 2% drop, no load to full load is permitted, what kilowatt output would be obtained (neglect leakage)? What primary e.m.f. necessary for 110 volts on the secondary, at full load? (*3 min.*)

5. A 3-kv-a., 10 to 1 transformer giving 110 volts on the secondary and having equal primary and secondary losses has a regulation of 2%; what must be the resistance of each coil and what is the drop in each? Neglect magnetic leakage and hence the reactance of the coils. (*3 min.*)

6. A transformer has two primary coils each of 900 turns and two secondaries, each of 90 turns; with the former in series the transformer is suitable for use on a 2200-volt system; for what other e.m.f. can the primary coils be connected, and what secondary e.m.f.'s can be obtained in each case? (*1 min.*)

7. A transformer has 2 secondary coils made up each of 48 turns of No. 8 wire, the length of the turn being 2 ft. and the

resistivity 12; with the coils in parallel the transformer is to give 110 volts at full load. Using 1200 circular mils per ampere, required the current that the transformer will give at this pressure; also the current and e.m.f. with the coils in series; the primary winding is made up of 2 coils each having 240 turns of the same mean length and using the same current density; required the currents and e.m.f.'s in the primary with the coils both in series and in parallel; required also the secondary and primary resistances, the primary and secondary drops and the regulation (neglect magnetizing current). (*10 min.*)

8. A 4-kilowatt, 10 to 1 transformer has 100 square centimeters cross-section of iron and with 600 turns in the primary has a density at 1000 volts of 6500; what would the density become if used on a 1200-volt system? If the frequency were decreased 10%, what would it be? Also if the area were made 125. Also if the turns were changed to 500. (*5 min.*)

9. Two transformers have the same iron volume but different windings, so that B is equal to 4000 and 6000 respectively. Required the ratio, (a) of the hysteresis losses and (b) the eddy current losses. (*4 min.*)

10. The cross-section and hence the volume of the iron in a transformer is increased 20%; with the same winding, what changes will result in the hysteresis loss and in the eddy current loss. What changes would then have to be made in the winding to bring each of these losses back to its former value? (*10 min.*)

11. Without changing the iron and e.m.f. of a transformer the number of turns is increased 10%. What changes in the hysteresis and eddy current losses will result? If in this transformer the copper and iron losses are equal, what will be the percentage change in the total loss (neglect the eddy loss). (*8 min.*)

12. A 50-kilovolt-ampere transformer has 210 watts hysteresis and 32 watts eddy current loss. If the magnetic density in this transformer is 9000, what would be the effect on the hysteresis, eddy and total iron loss of increasing it to 11,000? Of reducing it to 7000? Use 1.7 for the hysteresis exponent. (*7 min.*)

13. In problem 12 if there were no change in density, but a change from 60 to 25 in the frequency, what would the losses become? (*4 min.*)

14. If in problem 13 the impressed e.m.f. were kept constant,

what changed loss would result from the combined changes in frequency and density? (*6 min.*)

15. If 4750 be the highest density (maximum) allowable in a 5-kilovolt-ampere, 60-period, 10 to 1 transformer on 1150 volts primary, how many secondary turns must be used if the area of the iron is 112 square centimeters? (*4 min.*)

16. A 20-kilovolt-ampere transformer, designed for a 60-period circuit, and having losses as follows: Hysteresis, 110; eddy current, 19, and copper loss, 272, is to be used on a 140-period circuit. If, at the density employed, the hysteresis loss per cycle varies as $B^{1.7}$, what will be the efficiency in each case (neglect the change in copper loss). (*5 min.*)

17. A 1500-watt transformer used on 1000 volts has losses as follows: 28 watts hysteresis, 4.5 watts eddy current, and 40.6 watts copper. It is also run on a 600-volt circuit; with the same current output and neglecting the change in the primary current, required the efficiency in each case. (*4 min.*)

18. A 30 kv-a., 1100 to 110-volt transformer has a no load loss of 165 watts, and primary resistance of 0.25; find the resistance of the secondary and determine the efficiency of the transformer at full load, $\frac{3}{4}$, $\frac{1}{2}$ and $\frac{1}{4}$ load. Plot these results. Neglect the effect of the exciting current. (*10 min.*)

19. A 2400 to 120 volt, 20-kilovolt-ampere transformer has a primary resistance of 1.9 ohms, and an iron loss of 129 watts; required the all-day efficiency, if the load is as follows:

Number of hours	16	$\frac{1}{2}$	$\frac{1}{2}$	2	3	2	
Per cent of full load	0	100	75	60	50	25	(*10 min.*)

20. A 2500-watt transformer has an iron loss of 32 and a copper loss of 53 watts at full load; the primary and secondary losses are equal; required the efficiencies at $\frac{4}{4}$, $\frac{3}{4}$, $\frac{1}{2}$ and $\frac{1}{4}$ load; also the all-day efficiency if the transformer runs 2 hours at full load, 4 hours on $\frac{1}{2}$ load and 18 hours on no load. (*10 min.*)

21. The total volume of iron in a certain transformer is 12,400 cubic centimeters. The iron used is a silicon steel, having a constant of 7×10^{-11} for watts hysteresis loss per cycle per cubic centimeter and an exponent of 1.7. The eddy current loss coefficient may be taken as 4×10^{-15} and the exponent as 2. What will be the hysteresis, eddy and combined iron loss for B = 10,000 per square centimeter and 60 cycles per second? (*5 min.*)

22. A 10-kilovolt-ampere, single-circuit or auto-transformer is designed for 220 to 110 volts and a current density of 1000 circular mils per ampere; what should the areas of the two parts of the winding be? Also for the following ratios of transformation: 220 to 160 volts and 220 to 50 volts. What are the relative weights of copper for these different ratios? (*8 min.*)

23. Determine the wire areas and relative weights of two-circuit transformers for the same service as in problem 22. Also compare the weights of single- and two-circuit transformers for each case. (*12 min.*)

24. A 2-kilovolt-ampere auto-transformer is wound with No. 12 and No. 9 wire; for what primary and secondary voltages is it available if 1000 circular mils per ampere be allowed. Use the No. 9 wire as secondary. (*5 min.*)

25. A 5-kilovolt-ampere transformer for changing from 220 to 150 volts is to be built; with 1500 circular mils per ampere, 3 feet length of turns and 100 turns in the primary, how many pounds of copper would be saved by using a single-circuit design? Take the weight of a mil foot as 3.03×10^{-6} pounds and add 2% (approximate for large wires) for double-cotton-covered insulation. (*8 min.*)

26. Repeat problem 25, except with a 240-volt secondary. (*8 min.*)

27. In the Northwest Station of the Chicago Commonwealth Edison Company, auto-transformers are used to step up the power generated from 4500 to 9000 volts, the transmission voltage. Using 650 amperes per square inch, what would be the cross-section area of the primary and secondary parts of the winding of a 6600 kilovolt-ampere transformer for this purpose? (*2 min.*)

28. Three standard 2200- to 220-volt transformers are connected with their primaries in Y on a 2200-volt, 3-phase system, while their secondaries are connected delta-wise; what will be the e.m.f. on the secondaries? (*1 min.*)

29. It is desired to put taps on three 10 to 1 transformers, each having 80 turns in the secondaries so that when the primaries are connected in delta on a 1100-volt system, the secondaries can be connected in Y and give 110 volts between their terminals; how many turns from the neutral must the taps be placed? (*3 min.*)

30. Two standard 2200- to 220-volt transformers, each having

150 secondary turns, are to be used, by means of taps, to transform from 2200-volt, 2-phase to 220-volt, 3-phase. Where must the taps be put? What would the voltages on the 3-phase system be if the whole secondary were used? *(3 min.)*

31. Three transformers to transform from 1000 to 100 volt, 3-phase are to have the primaries connected Y and the secondaries connected delta. If the secondaries have 60 turns each, how many turns must the primaries have? *(2 min.)*

32. Three transformers connected in delta are supplying 100 amperes to a three-phase system. What is the current in the transformers? One of these transformers burns out and is removed; the system continuing to draw 100 amperes, what is the current in the two remaining transformers? Solve graphically. *(10 min.)*

33. Explain how two identical transformers without taps can be connected to give a 3-phase system with e.m.f.'s of 220, 311 and 220 volts when fed from a 1100-volt, 2-phase system. What will be the secondary e.m.f. and transformation ratios of the transformers? No changes are to be made in the windings. *(3 min.)*

34. It is required to design two transformers which can be used on a 6600-volt, 2-phase system to give either 2-phase or 3-phase, 3-wire systems at 220 volts; 2 volts per turn are to be allowed; the transformers have 2 coils in the secondaries and a tap is to be used. State numbers of turns in coils, location of tap and methods of connecting transformers for both systems. *(4 min.)*

35. Three 1000- to 100-volt transformers, A, B and C, are connected delta, both primary and secondary. Taps are taken out of the secondary as follows: (1) Between A and B; (2) 86.6% along B (from A); (3) middle of C; (4) 86.6% along A (from B). Show graphically what the e.m.f.'s between (1) and (3) and between (2) and (4) will be and what will be their phase relation. *(6 min.)*

36. Given two suitably wound transformers properly connected to give 400-volt, 3-phase e.m.f. by the Scott method. Construct the T-shaped diagram by the revolution of which around the junction of the two lines the 3-phase e.m.f.'s set up can be produced. By the rotation of this diagram construct first the three sine e.m.f. curves produced by the three vectors making up the "T," then by the combination of these with proper signs draw three 120-degree e.m.f.'s which they produce. *(30 min.)*

37. The same as problem 36, except that the 120-degree e.m.f.'s

are to be plotted directly from inspection of the projections of the "T" vectors. (*12 min.*)

38. Two 1100- to 110-volt transformers of the usual type and operated on a 1100-volt, 2-phase line can have the secondaries connected in two different ways to produce unbalanced 3-phase systems in which two of the e.m.f.'s are equal. By revolution of the appropriate diagrams, construct the e.m.f. curves for these two cases. (*30 min.*)

39. The hysteresis curve of a sample of steel containing 0.184% silicon is given by the following points:

H.	B.	H.	B.	H.	B.
1.4	0	8	10,700	2	8,000
2	2,850	10	11,500	1	6,700
3	5,300	8	11,200	0	4,800
4	7,000	6	10,700	−1	2,100
6	9,400	4	9,600	−1.4	0

If a transformer is built of this steel having a maximum density of 11,500, a length of magnetic circuit of 50 centimeters and 100 primary turns; also if the impressed e.m.f. is a sine curve; plot the curves of primary current for no load and for a non-inductive load of 10 amperes. (*30 min.*)

40. On the no-load test of a transformer; the voltmeter is connected inside of the ammeter and takes 0.05 ampere. The test shows 20 watts iron and instrument loss and the e.m.f. is 100; find the magnetizing current if the current read on the ammeter is 3 amperes. (*5 min.*)

41. Construct the sine waves for the component 3-phase parts of the 2-phase e.m.f.'s obtained by the connection described in problem 35 and by combining these derive the 2-phase sine curves. The 3-phase e.m.f.'s are each 100 volts. (*30 min.*)

CHAPTER X

TRANSFORMER DIAGRAMS AND REGULATION

Note. — Scale all quantities asked for. If problem V-22 has not been taken, include here. "Magnetizing current" is taken as the magnetizing or wattless component of the exciting or no-load current. The angle as well as the length of vector is required. In all problems unless otherwise stated or implied the mean length of turn and the current density in the two windings will be taken as the same. Note also that to adapt the problems to easy graphical solution the impedance drop, magnetizing current and iron losses have been exaggerated as compared with those usually found in commercial transformers.

1. A transformer has 600 primary and 60 secondary turns; 120 magnetizing ampere-turns are necessary; draw the ampere-turn diagrams for currents of 0, 10 and 20 amperes, secondary non-inductive load, and find the primary currents and lags. (See note above.) (*7 min.*)

2. Draw the same loads both lagging and leading the e.m.f. by 30 degrees, and find the primary currents and lags. (*10 min.*)

3. A 5 to 1 transformer with 80 secondary turns, takes 120 magnetizing ampere-turns; what are the primary currents and power factors for 0, 4 and 8 amperes, non-inductive load? (*8 min.*)

4. A 5 to 1 transformer has a secondary e.m.f. of 2200, a magnetizing current in phase with the flux of 2, and losses of 5 kilowatts; draw diagrams for loads of 60 amperes, both when lagging and when leading 30 degrees, and find the primary e.m.f., currents and power factors. (See note above.) (*13 min.*)

5. Same as problem 4, except that the coils have resistances of 52 and 1.8. Find also the full-load transformation ratio. Refer the phase angles to the induced e.m.f. (*25 min.*)

6. A 10 to 1 transformer with 220-volts secondary induced e.m.f. and a load of 400 amperes has 1.1 kw. iron losses and a magnetizing current of 2 amperes; draw and scale diagrams for secondary power factors of 80% and 40%, and find the primary currents. (*15 min.*)

7. If in problem 6 the resistances are 4.8 and 0.04, find the primary currents and power factors, and the terminal voltages. (*30 min.*)

8. Draw the three sine curves for the primary, secondary and magnetizing ampere-turns of problem 1, with 20 amperes in the secondary. (*25 min.*)

9. Repeat problem 8, with the lagging current of problem 2. (*25 min.*)

10. A 5 to 1 transformer has a primary induced e.m.f. of 1200 volts, the resistances are 3.1 and 0.13 ohms, the magnetizing current 3.4 amperes and the iron losses 660 watts; draw the diagrams for a non-inductive load of 100 amperes, and with the same load lagging 30 degrees behind the induced e.m.f.; find the terminal e.m.f.'s and primary currents. (*20 min.*)

11. If in problem 10 the leakage reactances are 6.2 and 0.26 ohms, draw the diagrams there called for, and find the primary currents and the transformation ratios. (*30 min.*)

12. The secondary current is 10 amperes lagging 30 degrees behind the terminal e.m.f. The induced e.m.f. is 100 volts, the secondary resistance 1 ohm, and its equivalent reactance 2 ohms. Draw the diagram and determine the secondary terminal e.m.f. and its lag. (*5 min.*)

13. A 2 to 1 transformer, giving 500 volts induced secondary e.m.f., has a magnetizing current of 5 amperes, an iron loss of 1200 watts, secondary resistance and reactance of 5 and 10 ohms; construct and scale the diagram and determine the primary current and terminal e.m.f.'s for a load having a resistance of 20 and a reactance of 4 ohms. See note, page 84. (*25 min.*)

14. For the transformer of problem 13, construct the sine waves of e.m.f.'s actually induced by all flux in the primary and secondary coils, also the curves of resistance drops and of terminal e.m.f. (*30 min.*)

15. A transformer has 150 primary and 75 secondary turns, a magnetizing current of $\frac{1}{2}$ and a secondary current of 10. The iron loss is 120 watts. The secondary induced pressure is 100. Required the primary current both when the secondary circuit is non-inductive and when a lag of 30 degrees behind the induced e.m.f. is present; find also the tangent of its lag in each case. (*5 min.*)

16. A 3 to 1 transformer has 190 secondary turns. The mag-

netizing current is 0.8 ampere, the iron loss 200 watts; r_1 is 0.9, r_2 is 0.1; with 300 volts induced e.m.f. on the primary and 20 amperes in the secondary find graphically the impressed primary e.m.f. and the primary current with its lag; and also the secondary induced and terminal e.m.f.'s for the following cases: (a) With the current lagging 15 degrees behind the induced e.m.f., (b) in phase with it, and (c) leading it by 15 degrees. (*26 min.*)

17. A transformer has 200 secondary and 400 primary turns; iron losses, 250 watts; r_1, 1.2 and r_2, 0.35 ohm; magnetizing current, 0.6; primary reactance, 2.4 ohms and secondary, 0.6. With 500 volts induced e.m.f. in the primary, construct diagrams for a secondary current of 20 amperes; (a) in phase with the secondary terminal e.m.f., (b) lagging 30 degrees; (c) leading 30 degrees, relative to the terminal e.m.f. Also determine the actual ratio of transformation in each case. (*50 min.*)

18. The secondary induced e.m.f. of a transformer is 200 and maintained constant; r'' equals 0.2, x'' equals 0.6, with a constant current of 200 amperes. Determine the secondary terminal e.m.f. for lags of 90, 60, 30 and 0 degrees behind the induced e.m.f. and leads of the same amounts. (*10 min.*)

19. A 2 to 1 transformer with constant primary impressed e.m.f. of 100 volts has a secondary resistance of 0.02 ohm and reactance of 0.06 ohm. Neglect iron loss and reluctance and transfer the primary impedance drop to the secondary winding; then determine the regulations for a load of 100 amperes with lags of 0, 30, 60 and 75 degrees behind the revolved primary terminal e.m.f.; also for 30- and 60-degree lead, and for unity power factor of the outside circuit. Lines may be used to represent the primary and secondary impedance drops. (*30 min.*)

20. The same as problem 19, except that the resistance is 0.06 ohm and the reactance 0.02 ohm. Compare the results obtained with those of problem 19. (*30 min.*)

21. Given a transformer designed to transform from 300 to 100 volts, $r'' = 0.1$, $x'' = 0.2$, no-load current neglected. Draw diagrams for the following cases: (a) No load, and (b) a load of 50 amperes lagging 30 degrees behind the induced e.m.f. Under (b) make both regular diagrams and revolved diagrams with all resistance and reactance referred to the primary. Assume (1) primary terminal e.m.f. raised to keep induced e.m.f.'s same as at no load; (2) ditto to keep secondary terminal e.m.f. same as at

no load; (3) to keep primary terminal e.m.f. unchanged. Scale all vectors and determine a regulation for each case. (*20 min.*)

22. Draw a typical diagram for a constant-potential to constant-current transformer, (a) with a large number of lamps on the circuit and (b) with one or two lamps. (*10 min.*)

23. Draw complete diagrams for a transformer without iron core, (a) with the coils wound together, turn for turn, and (b) for the coils slightly separated. Explain the effects of these conditions upon the form of the diagram. (*15 min.*)

CHAPTER XI

SYMBOLIC EXPRESSIONS AND METHODS

1. A current of 10 amperes lags 30 degrees behind the impressed e.m.f. of 100 volts. Find graphically the conductance, susceptance and admittance regarding these as constants which multiplied by the e.m.f. give the power and wattless components of the current and the current itself. Check by finding the relation of these quantities to the resistance, reactance and impedance. (*4 min.*)

2. Required symbolic expressions for the following vectors at the angles given: (a) 3.2 cm., 25 degrees; (b) 6.0 cm., 100 degrees; (c) 4.1 cm., 225 degrees; (d) the vector sum of (a) and (c). Check graphically. (*15 min.*)

3. Give symbolic expressions for the following vectors and for their sum: 1″, $\tan^{-1}\frac{1}{2}$; 2″, $\tan^{-1} 2$; 3″, $\tan^{-1}(-1)$. (*5 min.*)

4. Obtain symbolic expressions for e.m.f.'s of 20 volts, making $+ 30$ degrees with horizontal; and 30 volts making $+ 45$ degrees; give the expression for their sum and find its absolute value and the tangent of its angle; also check graphically. (*10 min.*)

5. The e.m.f.'s around two reactive circuits in series are 20 and 30 volts, and the power factors are 0.5 and 0.707. Find by symbolic method the combined e.m.f. (*3 min.*)

6. Two currents of 10 and 15 amperes in parallel circuits lag behind the e.m.f. by angles $\tan^{-1}\frac{1}{2}$ and $\tan^{-1}\frac{1}{3}$; by symbolic method find sum and its angle of lag. (*5 min.*)

7. Two series circuits having resistances of 3 and 4 ohms and inductances of 0.01 and 0.05 henry are in series upon a 100-period system, and take 5 amperes; obtain the symbolic expression for the e.m.f. and also its absolute value and lag. (*5 min.*)

8. Solve problem 5, Chapter V, by the symbolic method. (*6 min.*)

9. Solve problem 6, Chapter V, by the symbolic method. (*20 min.*)

10. Two parallel circuits have resistances of 8 and 3 and reactances of 6 and 4; find the conductance, susceptance and the admittance of the combined circuits; also with 100 volts applied

the symbolic expression for the currents in each circuit and the total current; also the absolute values and tangents of angle of lag. Check graphically. (*10 min.*)

11. Two parallel circuits have resistances of 1 and 5 ohms and reactances of 7 and 5 ohms; by the symbolic method find the impressed e.m.f. with a total current of 100 amperes; check graphically. (*6 min.*)

12. Solve problem 29, Chapter V, by the symbolic method. (*5 min.*)

13. Solve problem 41, Chapter V, by the symbolic method. (*15 min.*)

14. Solve problem 44, Chapter V, by the symbolic method. (*12 min.*)

15. Solve problem 4, Chapter VI, by the symbolic method. (*5 min.*)

16. Solve problem 10, Chapter VI, by the symbolic method. (*8 min.*)

17. A 500-kv-a., 2000-volt single-phase transmission line has a resistance of 0.22 and an inductive reactance of 0.36 ohm. What e.m.f. must be generated to give 2000 volts with a unity power-factor load? (*4 min.*)

18. Repeat problem 17, with the power factor 70.7%. (*5 min.*)

19. The no-load or exciting current of a 6000 to 2200, 100-kv-a. transformer is 0.47 ampere, the iron loss is 1020 watts. By the symbolic method determine the total primary current for full-load secondary current at unity power factor (referred to secondary induced e.m.f.); also find the magnetizing component. (*5 min.*)

20. Same as problem 16, except that the load current has a power factor of 70.7% referred to the induced e.m.f. (*4 min.*)

21. A 20-kv-a., 3000 to 220-volt transformer has a secondary resistance of 0.0126 ohm and a secondary reactance of 0.0110 ohm. With a secondary induced e.m.f. of 220 volts find the terminal e.m.f. (symbolic expression) for a load of incandescent lamps, having a resistance of 2.4 ohms. (*25 min.*)

22. Repeat with a full-load current lagging 30 degrees behind the induced e.m.f. (*15 min.*)

23. The primary resistance being 2.25 ohms and the primary reactance 1.96 ohms, find the primary e.m.f. and hence the regulation in problem 21. Neglect the exciting current. (*20 min.*)

24. Repeat problem 23, with a power factor of 86.6% referred to the induced e.m.f. (*20 min.*)

Note. — Further practice with the symbolic method may be obtained by solving any of the other problems where graphical solutions are called for.

CHAPTER XII

ALTERNATOR REACTIONS AND REGULATIONS

1. The maximum value of the effective back ampere-turns with one ampere through an alternator armature is 100. The maximum current is 20; plot on cross-section paper with scales, a curve showing the effectiveness of the armature coils in producing forward or back ampere-turns. Show the poles and plot the curves with position of the coil, relative to the poles as abscissæ. Plot also the current curve and by multiplication of ordinates plot a curve showing the instantaneous forward and back ampere-turns. Do this for: (a) unity power factor; (b) 30 degrees lag; and (c) 30 degrees lead of the current relative to the e.m.f. (*30 min.*)

2. A two-phase alternator has poles occupying half the pole pitch. There are 10 turns or 20 conductors in each coil of each phase; the maximum current is 100 amperes. Lay off the pole pieces on a piece of cross-section paper, and using the successive positions of the coils relative to the pole pieces as abscissae, plot a curve showing the combined number of forward or back ampere-turns due to the current in both phases, and for each position of the coil. Do this: (a) for unity power factor; (b) for 30 degrees lagging current; and (c) for 30 degrees leading current. (*15 min.*)

3. Same as problem 2, except that the cross ampere-turns are to be plotted. (*15 min.*)

800

4. On short circuit a certain 50-period, 2200-volt, 440-kv-a. generator requires 40-amperes field current to give 200 amperes its full-load current. On open circuit the e.m.f. corresponding to 40 amperes excitation is 1160 volts. What is the synchronous impedance? The resistance being 0.5 ohm, what is the synchronous reactance? (*3 min.*)

5. Using the "electro-motive force method" of determination, what would be the calculated regulation of the above machine on unity power factor? Also with 30 and 60 degrees lag? (*15 min.*)

6. The no-load magnetization curve of an 850-kv-a, 5000-volt, Y-connected alternator is given by the following data:

Ampere-turns								
2000	4000	6000	8000	10,000	12,000	14,000	16,000	18,000
Volts (to neutral)								
940	1900	2600	2950	3160	3340	3460	3550	3620

3625 ampere-turns give full short-circuited current of 98.5 amperes.

Resistance per phase (to neutral) 0.33 ohm.

Construct the above magnetization curve and the curve of short-circuit current with ampere-turns.

Construct also the pessimistic and optimistic zero-power-factor curves between terminal volts and field ampere-turns (Karapetoff, II, 143) and determine the two regulations for 5000-volts full-load zero power factor. (*30 min.*)

7. Determine also the pessimistic and optimistic values of regulation for unity and 80% power factor. (*20 min.*)

CHAPTER XIII

SYNCHRONOUS MOTORS AND GENERATORS

Note. — All graphical problems are to be worked on large sheets. Always draw the current vectors.

1. Two 110-volt alternators, for which ω is 400, are mechanically coupled and connected in series upon a circuit of 5 ohms and 0.005 henry. How much power will be given by each machine to the circuit when the e.m.f.'s of the two machines are 30, 45 and 90 degrees apart? (*30 min.*)

2. The same machines as in problem 1 are used in the same way upon a circuit of 2 ohms resistance and 6 ohms reactance. Determine the power for the same phase angles. (*30 min.*)

3. Two alternators each generate 2000 volts; each has the armature resistance, 2, the inductance, 0.07, and the frequency, 60. They are run in parallel and owing to throttling of one engine a phase displacement (from opposition) of 30 degrees results. How many kilowatts are being supplied by the motor action of the synchronizing current and how much copper loss results? Solve graphically. (*25 min.*)

4. A synchronous motor, running on a 2000-volt line, is over-excited so that with 10-amperes load its current leads the e.m.f. 30 degrees. A choke coil with 20-ohms reactance and $\frac{1}{2}$-ohm resistance is placed in series with it; what is the e.m.f. at the motor terminals? (*3 min.*)

5. A synchronous motor is run on a 440-volt, 60-period circuit and takes 20 amperes leading 30 degrees. If an induction coil with L, 0.01, is in series with it, what will then be the e.m.f. on the motor? (*3 min.*)

6. A synchronous motor running on a 1200-volt system has an armature resistance of 1.2 and reactance of 5.8 ohms. For a certain field current, the motor gives 1100 volts counter e.m.f. (neglect the change in this due to armature reactions). Construct the parallelogram diagrams for currents of 10, 25 and 40 amperes. Let the line e.m.f. vector be common to all three diagrams.

Determine the power factors of the line current in each case. (*30 min.*)

Note that in these problems an open scale and great care is necessary to get accurate results. The impedance e.m.f. triangle should be drawn to a larger scale than the motor e.m.f. The resistances in these problems are exaggerated as compared with commercial machines.

7. Repeat problem 6, with a higher excitation, giving a counter e.m.f. of 1200 volts. Determine also the power supplied to the motor in each case. (*35 min.*)

8. Repeat problem 6, with a counter e.m.f. of 1300 volts. Determine also the power transformed by the motor to mechanical energy in each case. (*35 min.*)

9. In the motor of problem 6 with a load adjusted for each case to 40 amperes, the excitation of the motor is changed so that the e.m.f.'s are respectively 1050, 1150 and 1250 volts. Construct the 3 diagrams for this case; determine the power given to the motor, the copper loss and the power transformed in each case. (*35 min.*)

10. The motor of problem 6 is run upon a transmission line having a resistance of 1.2 ohms, the generator e.m.f. is maintained at 1200 volts; construct the 3 diagrams for a counter e.m.f. of 1200 volts and obtain the tangents of the lag or lead of the current. (*30 min.*)

11. In the motor of problem 6 the resistance is made 2.4 and the reactance 11.6, that is the impedance is doubled. The line and motor e.m.f.'s both being 1200 volts, construct the diagrams for 10, 25 and 40 amperes and find the power factors for each case. (*30 min.*)

12. A motor is excited to 95 volts, the resistance is 0.1 and the reactance 0.8; the power taken by the motor is constant and its e.m.f. is lagging 15 degrees behind opposition to the current; if the current be 20 amperes, required the terminal e.m.f. With the same terminal e.m.f., what other motor e.m.f. will give the same current? Also, what motor e.m.f. will make the power-factor unity? (*15 min.*)

13. With the motor of problem 12 on a 100-volt circuit, find the motor e.m.f. to give minimum current for a load at 3 kw. With the same power transformed and the same motor excitation, what change in terminal e.m.f. would reduce the current to a new min-

imum; with this new line e.m.f. what further change in motor e.m.f. would reduce the current to still another minimum; determine also the value of the current for each case. (*20 min.*)

14. For the motor of problem 6, having a resistance of 1.2 and a reactance of 5.8 ohms and excited to 1100 volts, construct the circle diagrams for 10, 25 and 40 amperes with 1200-volts line e.m.f. and from these determine the power transformed to mechanical energy by the motor for each case. Find also the maximum load the motor will carry, and the current for that load. (*20 min.*)

15. Repeat problem 14, with a motor e.m.f. of 1200 volts. (*10 min.*)

16. Repeat problem 14, with the resistance doubled. (*10 min.*)

17. Repeat problem 14, with the resistance and reactance both doubled. (*10 min.*)

18. Find the maximum value that the motor e.m.f. can have with a line e.m.f. of 1200 for each of the impedances of problems 14, 16 and 17. (*5 min.*)

19. A synchronous motor running on a 220-volt line has a resistance of 0.18 and a reactance of 0.98, and is generating 210 volts. Construct the parallelogram diagram for an input of 4 kw. and determine the power factor of the line current. With the same power and line e.m.f. find the motor e.m.f.'s to give unity and 86.6% (leading) power factor. (*20 min.*)

20. With the same motor as in problem 19 construct the parallelogram diagram for 4 kw. with the current in opposition to the motor e.m.f. and determine the necessary e.m.f. of the motor. Note that this gives maximum output of the motor for a given current and *motor* e.m.f. (*10 min.*)

21. For the motor of problem 14 plot excitation characteristics for 10 and 30 kw.; use motor e.m.f.'s for abscissæ and currents as ordinates; show on the curves the range within which the motor will run. Use the circular diagram to obtain the points. (*45 min.*)

22. A motor having a resistance, 0.04 ohm, and a reactance, 0.25 ohm, is excited to 200 volts and run on 220 volts. Draw the circle diagrams for the case where the motor is taking no power and where it breaks from step, also for $\frac{1}{2}$ the latter load; determine from these the current and power in each case; also what would be the minimum generator e.m.f. on which the motor could run with the least load; also with a generator e.m.f. of 220 volts what

would be the maximum e.m.f. of the motor with which it could run as a motor? (*20 min.*)

23. Two 1100-volt alternators, A and B, each having a resistance of 0.21 ohm and a reactance of 1.2 ohms are in parallel and are supplying a circuit having a resistance of 9.79 and a reactance of 3.8 ohms. Draw the parallelogram diagram for the following cases obtaining the terminal e.m.f. in each case; (a) the e.m.f.'s are equal and opposite; (b) owing to decrease in the driving power machine B lags 2 degrees behind opposition to machine A. Find the synchronizing current, the power it gives to B, the total current on each machine, and the power given by each. Neglect the synchronizing component in getting the terminal e.m.f. Note that the currents, while combined in the outside circuit, are in opposition in the local circuit. (*25 min.*)

24. A 5500-volt, 1500-kv-a., three-phase, Y-connected alternator, 83 r.p.m. 50-cycle, is to be used as a synchronous motor. The resistance is 0.3 ohm per phase, that is to the neutral. The reactance is 2.7 ohms per phase. Construct the parallelogram diagram, and find the motor voltage necessary to give unity power factor on a 5500-volt line, with an input of 1500 kw. into the motor. Find also the current and power factor with an excitation of 5500 volts. (*30 min.*)

25. Check the results of problem 24 by the symbolic method. (*30 min.*)

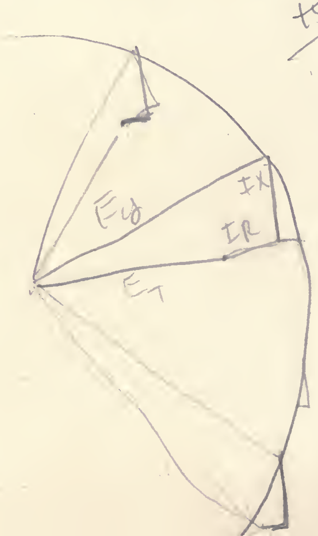
26. Construct the circle diagram for the alternator of problem 24 and determine the maximum load it will carry when excited to 5456 volts. (*10 min.*)

3

$\frac{1500 \times 1000}{5500\sqrt{3}}$

11

157 amps



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CHAPTER XIV

SYNCHRONOUS CONVERTERS

1. Draw 2 diagrams showing 4-pole, parallel-wound synchronous converters for 3 and 4 phases respectively, and show the location of the brushes and connections to the slip rings on these diagrams. (*8 min.*)

2. Construct a table giving in per cent for a direct-current generator and for converters single-phase and 3, 4 and 6-phase, the relation of maximum and effective e.m.f.'s and of the effective alternating currents in the armature windings and in the leads from the brushes. Take the e.m.f. and line current for the direct-current generator as one hundred in each case. (*15 min.*)

3. A converter gives 110 volts direct current; determine graphically the maximum e.m.f. between adjacent brushes of the alternating-current side if 4-phase, also if 3-phase and 6-phase. From these calculate the effective e.m.f.'s. (*8 min.*)

4. In problem 3 if the direct current is 65 amperes and the efficiency 100%, what is the effective single-phase line current? Determine the effective 3, 4 and 6-phase currents in the line. Obtain these values directly by use of the effective e.m.f.'s. (*8 min.*)

5. Converters are placed upon 2000-volt systems, single, 3, 4 and 6-phase. Find the direct-current e.m.f. in each case. (*3 min.*)

6. The converters of problem 5 are fed in each case with 250 amperes alternating current; determine the direct current in each case. (*15 min.*)

7. The converters of problem 5 are each carrying 150 amperes alternating current (sine wave), in the armature conductors; required the alternating line current and the direct current delivered. (*9 min.*)

8. A double-current generator is designed to give 230 volts across the outside of a three-wire system. The alternating-current side supplies 3-phase current to step-up transformers. For what e.m.f. must they be designed. If the machine were 4-phase what

would be the e.m.f. of the transformers using two transformers; also using four transformers? (*4 min.*)

9. A 3-phase railway converter is giving 57 kilowatts at 550 volts, with an efficiency of 93%; what will be the alternating current e.m.f.? With a 10 to 1 transformer in the circuit what will be the amperes for each line of a 3-wire transmission? (*5 min.*)

10. A single-phase converter gives 100 amperes to the direct-current circuit. Plot the currents in three conductors, one midway between the slip-ring connections, one adjacent to one of these connections, and a third halfway between the other two. (*20 min.*)

11. Repeat problem 10, with a 3-phase converter. (*20 min.*)

12. Repeat problem 10, with a 4-phase converter. (*20 min.*)

13. A single-phase converter gives 100 amperes to the direct-current circuit with a lag of 30 degrees in the alternating current. Plot the currents in each of 3 conductors of a segment of the armature lying between two slip rings. Take the first conductor of the segment, the last conductor and one midway between these. (*20 min.*)

14. A 3-phase converter gives 100 amperes to the direct-current circuit, with the alternating current leading 30 degrees. Plot the current in each of 3 conductors of a segment of the armature lying between two slip rings. Take the first conductor of the segment, the last conductor and one midway between these. (*20 min.*)

15. A certain four-pole, single-phase, synchronous converter for 220 volts on the direct-current side has 568 conductors and 2.63×10^6 maxwells per pole. At what r.p.m. would it run as an inverted converter and what frequency would it give on its alternating-current end? When the machine gives full-load current with a large lag, the back reaction of the armature cuts down the field flux to 4.1×10^5. Neglecting armature drop, at what speed would the converter tend to run under these conditions, and what would be the consequences? (*6 min.*)

16. A 60-period, 3-phase converter has in series with it a reactance of 20 ohms with negligible resistance; the line e.m.f. is 1100 volts; what will be the generated direct-current e.m.f. on a load of 20 amperes (alternating current), when the field is excited to give 30 degrees lag, unity power factor and 30 degrees lead? (*10 min.*)

17. A converter has a capacity of 125 kw. when used single-

phase; what is its capacity as a three-phase converter; also as a 4-phase and a 6-phase converter; also as a direct-current generator? (*10 min.*)

18. A certain converter is wound for a 3-phase system, with 50 pounds of copper; with the same heating, what would be the saving in copper, if this machine were to be connected and used for the same output on a 4-phase system; also for a 6-phase? (*7 min.*)

19. Plot as ordinates the currents for one period, in a conductor $\frac{1}{12}$ of the pole-pitch distant from the collector-ring connection in a 3-phase converter, giving 130 amperes direct current. (*5 min.*)

20. For an 8-phase converter, determine the e.m.f. and current relations and the ratio of its power capacity to the same machine used as a direct-current generator. (*10 min.*)

21. A 3-phase, 2-pole converter gives 250 amperes, direct current; when the ring connection has passed the brush 30 degrees, plot the curve of current in each conductor. (*15 min.*)

CHAPTER XV

POLYPHASE INDUCTION MOTORS

1. Lay off on two axes, making 60 degrees with each other, the successive sets of field values due to a two-phase system of currents in coils at right angles to the above axes. Combine these and hence obtain a polar curve showing the strength of the revolving field. Note also the angular velocity of the field at different points. (*10 min.*)

2. Lay off on three axes, making 120 degrees with each other, the successive sets of field values due to a three-phase system of currents in three coils at right angles to these axes. Combine the three fields of each set and thus obtain a polar curve showing the strength of the revolving field. Note also the angular velocity at different points. (*15 min.*)

3. A 12-pole (per phase) induction motor is running on a 60-period circuit; what is the frequency of the current in the secondary, when it is running at 600, 500, 300 and 0 r.p.m.? (*4 min.*)

4. Construct a table showing synchronous speeds in r.p.m. for 2-, 4-, 6-, 8-, 10- and 12-pole motors at frequencies of 100, 60, 40 and 25. (*9 min.*)

5. Draw a series of diagrams showing a cross-section perpendicular to the shaft, of the rings and of the field or primary conductors of a 6-pole, 2-phase motor, and show by dotted lines the positions of the field corresponding to $\theta = 0$, 45, 90 and 135 degrees in $i_a = I_a \sin\theta$. Draw the coils and field for one-half of the ring only. Letter the phases A and B and indicate the successive position of a particular pole by marking with an X. (*15 min.*)

6. Repeat problem 5 with a 4-pole, 3-phase motor and corresponding to $\theta = 0$, 30, 90 and 180 degrees. (*20 min.*)

7. The stator and rotor of a 440-volt induction motor are both Y-connected. The stator current is 18 and the rotor current 108. If the slip is 4%, what e.m.f. is set up in the rotor circuit between neutral and one slip ring? (*3 min.*)

8. A 300-h.p., 440-volt, 50-cycle, 12-pole motor has a delta-

connected primary and Y-connected secondary. The full-load efficiency is 92% and the power factor is 85%. There are 432 stator and 338 rotor conductors. Neglecting losses, what will be the full-load currents in stator and rotor, and the e.m.f. per phase (to neutral) in the rotor when at standstill? The resistance per phase being 0.022 and the reactance neglected, what will be the rotor e.m.f. and the slip at rated load? (*10 min.*)

9. If the reactance at standstill of the rotor of problem 8 is 0.20 ohm, and if an outside resistance of 0.218 ohm be connected by the slip rings into each phase, at what speed will the motor run when taking full-load current? (*9 min.*)

10. Find the equivalent single-phase value of the rotor resistance and of the rotor and stator currents at rated load in problem 8. (*5 min.*)

11. A 25-cycle, 200-h.p., 1000-volt, Y-connected induction motor has a wound Y-connected rotor with slip rings and a transformation ratio of 3.6. The resistance per phase is 0.01. If the inductance per phase is 0.00064 henry, what would be the starting current with short-circuited slip rings? Also what would be its phase angle with the flux? The full-load slip being 3%, what will be the current and its angle? What resistance per phase would have to be inserted to get 300-amperes starting current in the primary, and what would be the phase angle of the current in the secondary? Neglect the primary losses. (*25 min.*)

12. The conductors of an induction motor are divided into groups numbered from 1 to 48, all wound in the same direction and having the ends marked + and −. Show to what each end of each section must be connected (that is to a main or the + or − end of another coil) to give: (a) a 4-pole, 2-phase motor; (b) a 12-pole, 2-phase motor; (c) a 4-pole, 3-phase motor, delta-connected; (d) an 8-pole, 3-phase motor, Y-connected. (*25 min.*)

13. The total no-load losses in a 381-volt, 45-h.p., Y-connected motor are 1416 watts. The magnetizing ampere-turns necessary for the air gap are 184, and for the rest of the circuit 36, maximum per pole per phase. The turns per pole per phase are 10. What is the effective no-load current and what is its power factor? Assuming the magnetizing current constant and neglecting leakage, what would be the power factor with an input of 20 kw.? Note that, in this case, leakage reduces the power factor about 5%. (*25 min.*)

14. A 440-volt induction motor gives the following data on test: No-load current, 4.0; power factor, 0.3; current for blocked rotor, 50; and power factor, 0.5; primary resistance, 2.3 ohms. Construct the circle diagram of the motor and determine the rotor current, power factor, output, input, efficiency, per cent slip and torque in synchronous watts for a stator current of 20 amperes. Determine also the maximum power factor and torque with the corresponding outputs. *(60 min.)*

15. A 220-volt, 20-h.p., delta-connected motor takes 20 amperes per phase line current at no load and 270 amperes with blocked rotor. The corresponding watts per phase are 300 and 15,000. The stator resistance, as measured from line to line, is 0.1 ohm. Construct curves of line current, input, efficiency, per cent slip and power factor with horse-power output as abscissæ. Get four sets of points besides those for no load and blocked rotor. Give the above items corresponding to 138.5 amperes, line current, input. *(90 min.)*

16. A 350-h.p., 500-volt, 3-phase motor, 300-r.p.m., 50-cycles has both stator and rotor star-connected. It gives on test the following data: With no load the current is 145 amperes and the power 1.1 kilowatts. With blocked rotor the current is 1600 amperes and the power factor 0.28. The stator resistance per phase is 0.015 ohm. Construct the circle diagram and by means of it plot the speed-torque curve. Determine the resistance of the rotor circuit and that which must be added to give maximum torque at starting. *(60 min.)*

17. Using the formula $\frac{T'}{T''} = \frac{r'(r''^2 + x^2s^2)}{r''(r'^2 + x^2s^2)}$,

where r' and r'' are two secondary resistances and x is the secondary reactance, 0.047, plot the speed torque curve for the motor of problem 16 which will give maximum torque at starting. Base this upon the rotor resistance as found in problem 16. *(60 min.)*

BROWN AND SHARP WIRE TABLE

B. & S. No.	Diameter, mils.	Area, circular mils.	B. & S. No.	Diameter, mils.	Area, circular mils.
4°	460	211,600	21	28.5	812.3
3°	410	168,100	22	25.3	640.1
2°	365	133,220	23	22.6	510.8
0	325	105,620	24	20.1	404.0
			25	17.9	320.4
1	289	83,520	26	15.9	252.8
2	258	66,560	27	14.2	201.6
3	229	52,440	28	12.6	158.8
4	204	41,620	29	11.3	127.7
5	182	33,120	30	10.0	100.0
6	162	26,240	31	8.9	79.2
7	144	20,730	32	8.0	64.0
8	128	16,380	33	7.1	50.4
9	114	13,000	34	6.3	39.7
10	102	10,400	35	5.6	31.4
11	90.7	8,226	36	5.0	25.0
12	80.8	6,529	37	4.4	19.4
13	72.0	5,184	38	4.0	16.0
14	64.1	4,108	39	3.5	12.3
15	57.1	3,260	40	3.1	9.6
16	50.8	2,580			
17	45.3	2,052			
18	40.3	1,624			
19	35.9	1,288			
20	32.0	1,024			

Note. — The system of sizes, known as the B. & S. gauge, represent a geometric series between No. 4/0 and No. 36, and involve, therefore, large numbers of decimals for their exact expressions. In preparing the above table the specifications of the American Society for Testing Materials, dated June 1, 1912, were taken into consideration. These provide that for soft wires the permissible variation from nominal diameter shall be for wire 0.01 inch in diameter and larger, 1% over or under. For wires less than 0.01 inch in diameter, 0.1 mil over or under. For medium hard and hard wire 1% variation is allowed for wires 0.1 inch and larger, and 1 mil for smaller wires. In expressing the size of such wires not more than three decimals of an inch shall be used, namely, whole mils. The specifications further condemn the use of large numbers of decimals in expressing the diameter of wires, and recommend that actual diameters rather than gauge numbers be used.

MAGNET WIRE

For magnet wire double-cotton-covered, to obtain the diameter add for wires from

4/0 to 8	14 mils
9 to 15	11 mils
16 to 34	9 mils
35 to 37	8½ mils
37 to 40	8 mils

to the diameter of the bare wire.

RESISTIVITY

Mil-foot

Temp. in Cent.	Temp. in Fahr.	Copper.	Aluminum.	Typical iron.
0	32	9.59	16.0	67.0
5	41	9.78	16.3	69.0
10	50	9.97	16.6	71.0
15	59	10.14	16.9	73.0
20	68	10.35	17.3	75.0
25	77	10.55	17.6	77.0
30	86	10.75	17.9	79.1
35	95	10.95	18.2	81.1
40	104	11.16	18.5	83.1
45	113	11.36	18.9	85.1
50	122	11.57	19.2	87.1
55	131	11.77	19.5	89.1
60	140	11.98	19.8	91.1
65	149	12.19	20.1	93.1
70	158	12.40	20.5	95.2
75	167	12.61	20.8	97.2
80	176	12.82	21.1	99.2
85	185	13.03	21.4	101.2
90	194	13.23	21.7	103.2
95	203	13.43	22.1	105.2
100	212	13.64	22.4	107.2

TYPICAL B-H OR MAGNETOMOTIVE-FORCE CURVES FOR DIFFERENT IRONS

Kilo-gausses.	H_c=M.M.F. per centimeter.			Kilo-gausses.	H_c cast iron.
	Sheet steel.	Cast steel.	Wrought iron.		
3	1.3	2.9	2.0	3	5.0
4	1.6	3.4	2.5	3.5	6.5
5	1.9	3.9	3.0	4	8.5
6	2.3	4.5	3.5	4.5	11.2
7	2.6	5.1	4.0	5.	14.5
8	3.0	5.8	4.5	5.5	18.5
9	3.5	6.5	5.0	6.	23.5
10	3.9	7.5	5.6	6.5	30.0
11	4.4	9.0	6.5	7.	38.5
12	5.0	11.5	7.9	7.5	49.0
13	6.0	15.2	10.0	8.	60
13.5	7.0	18.0	11.5	8.5	74
14	8.8	21.5	14.5	9	89
14.5	11.3	26.0	18.5	9.5	106
15	14.7	32.0	25.0	10	124
15.5	20.0	40.0	35.0	10.5	144
16	27.0	49.0	49.5	11	166
16.5	37.0	60.0	69.0	11.5	192
17	51.0	73.0	93.0	12	222
17.5	69.0	90.0	120	12.5	255
18	91.0	112	152	13	290
18.5	118	139	189	13.5	328
19	150	175	229	14	369
19.5	188	223	277	....	....
20	231	285	....	....	....
20.5	278	....	....	....	....
21	329	....	....	....	....
21.5	383	....	....	....	....
22	439	....	....	....	....
22.5	496	....	....	....	....
23	553	....	....	....	....
24	668	....	....	....	....
25	783	....	....	....	....

While these values represent fairly the average results obtained from good quality material, better values are sometimes obtained.

ANSWERS TO ACCOMPANY

ELECTRICAL ENGINEERING PROBLEMS

F. C. CALDWELL

NOTE.—These answers are usually carried further than the data given would warrant, in order to form a basis of comparison.

PART I

DIRECT CURRENT

CHAPTER I

1. 35, 25, 40.
2. 12, 24.
3. 70, 240, 24.
4. 0.00160, 0.00255, 0.0182, 129.55.
6. 25, 1.5.
7. 2, 1; 2, 2000.
8. 0.666, 0.0833; 1½, 12; 10, 6, 4; 12, 8.
9. 0.2, 0.033, 0.1111, 0.3666, 0.5, 1.166; 5, 30, 9, 2.727, 0.857.
10. 4.
11. 5, 3125, 5, 29.80.
12. 41.5, 0.415.
13. 53, 9½, 62½.
14. 200.

CHAPTER II

1. 5.68, 22.73, 181.8, 285.7; 32.29, 2.74%; 516.5, 1.11%; 33,060, 0.121%, 81,630, 2.26%.
2. 41,600, 5200, 1040.
3. 101.5, 203.0; 13.30.
4. 46,875, 59,675, 59,237.
5. 4, 14, 30; 32, 24, 14, 7, 2.
6. 12.62, 25.24.
7. 10.40.
8. 16.00.
9. 1.081.
10. 257.9.
11. 139.6, 360.4.
12. 0.5, 247.8, 0.0054, zero.
13. 3065, No. 15.

CHAPTER III

1. 7.373, 11, 5.5.
2. $17.90.
3. 6.24 cents.
4. 42.88.
5. 516.76, 3.35%, 335.2.
6. 510.57, 2.11%, 211.4.
7. 80.13, 11,950, 16.03, 16.03.
8. 1.613, 251.7, 14.43.
9. 80.

CHAPTER IV

1. 0.02771, 153.6.
2. 485, 73.49, 32,000.
3. 0.00025, 0.25, 500.
4. 0.24975, 249.75.
5. 48,000.

CHAPTER V

2. 1500, 238.7.
3. 756.0.
4. 3930, 2812.
5. 0.007854, 600.
6. 0.02356, 6750.
7. 940.
8. 496, 16, 160.
9. 7680.
10. 0.008398, 13.55.
11. 2.487, 7.025, 17.56, 36.29.
12. 22.96, 183.0, 1145, 4886.
13. 0.03466 cm., 400.
14. 785.
15. 0.1070.
16. 24.36.
18. 5.6, 657.
19. 5.35.
20. 38.53, 81,180.
21. 14.66, 36,850.
22. 18.30.
23. 1.3.
24. 291.6.
25. 1.278.
26. 12.29 × 24.58.

CHAPTER VI

1. 1440, No. 18.
2. 960, No. 20, 20,833.
3. 10.54.
4. 2110, No. 16.
5. 1364, No. 18.
6. 27.93.
7. 184.4, 20.96%.
8. 10,700, 930, No. 20, 1.024, 8320.
9. 4596, 1045, No. 19, 4250.
10. 300.
11. 2.935″, 374.3, No. 24, 8092, 0.4040.
12. 1950, 1273; 5.87″, 632.5, No. 22, 5097.
13. 9700 per pole, 16,130, No. 8, 82.5.
14. 31.92 for 7000, same.
15. 1.25, 7.430.

CHAPTER VII

1. 3.24.
2. 12.15.
3. 0.588.
4. 79.6.
5. 121.6.
6. 1667.
7. 14.07×10^6, 253.2 sq. in.
8. 512, 2.4%.
9. 33⅓.
10. 148.
11. 86.4.
12. 94.25.
13. 60 volts, 416.7 amp., 25 kw.; 256 bars, 5 × 5 mm.; 208.3 amp., 25 kw.
14. 227,272.
15. 500 volts, 80 amp., 40 kw., 0.74%.
16. 750 volts, 200 amp., 150 kw., 1.512%.
17. 255.4, 2.16%, 2.16%.
18. 220 volts, 136.4 amp., 30 kw.
19. 576 turns, No. 14.
20. 480 volts, 12.02 and 7.395 kw.
21. 8.82″.
22. 26.2%, 9.8%.
23. 122, 12.69.

CHAPTER IX

1. 100.
2. 4.648.
3. 0.003083.
4. 0.4917, 34.68, 17.05.
5. 0.1229, 69.36; 0.4917, 34.68; 0.01967, 173.4.
6. 0.169, 0.676, same.
7. 17.25, 9.75, none.
8. 27.194, No. 11 (6799 circular mils), 98.81.

CHAPTER X

1. 7000, 3500.
2. 75.6, 50.4; 1512, 1008.
3. $1833\frac{1}{3}$, $3666\frac{2}{3}$; $3666\frac{2}{3}$, $7333\frac{1}{3}$.
4. 6680, 1670; same; 26,720, 6680.
5. 0.7330, 0.3665.
6. 2630.
7. 485.1.
8. 71.63, 76.40.
9. 400, $133\frac{1}{3}$, 2127.
10. 8333, 1389, 5.01.
11. 1.25, 0.163″, 2.5, 0.326″.
12. 5547, 2133, 30.03, 0.2582; 6187, 1493, 21.02, 0.2881; 3093, 747, 10.5, 0.1441; 0.3228.
13. Max. B 7000, 8786, 14,144.
14. 253.

CHAPTER XI

1. 771.5, 1487, 2419, 3792, 6190; 1.21, 1.83, 2.79 amp.
2. For flux = 5×10^6, Ni = 5140, i = 2.85, e = 186; 3.06, 3.73 and 4.70 amp.
3. 27%, 3550, 20%.
4. For 200,000, Ni = 3804.
5. 9.85% decrease, 19.1% increase.
6. 14,110, 7.85 amp.; 478 volts, no.
7. 16.38, 19.31.

CHAPTER XII

1. $\frac{1}{2}$, $0.083\frac{1}{3}$.
2. 110, 0.1; 102.2, 22.
3. 505, 10; 502.5, 51.
4. I, 60, E, 101.
5. 118.4, 105.
6. 118.26, 105.14.
7. Reduced 23.1%.
8. 317.0, 433.8.
9. I, 3.67, E, 110.4; I, 62.0, E, 97.4; I, 51.3, E, 46.2 (3 points.)
10. I, 10, E, 21.5; I, 60, E, 129; I, 150, E, 142.5.
11. I, 5.3, E, 142.2; I, 55.8, E, 125.2; I, 75.2, E, 83.8.
12. I, 27, E, 217.1; I, 14.3, E, 192.7; I, 25.8, E, 156.3.
13. Full-load point, total characteristic I, 205.6, E, 576.5.
14. Full-load point, total characteristic I, 828.6, E, 569.47.

CHAPTER XIII

1. 81.62 degrees.
2. 50.26, 1.99.
3. 8.944 inches.
4. 85.7 degrees.
5. 25.45, 922.3.
6. 48.4, 154.1.

CHAPTER XIV

1. 917.9, 327.06.
2. 8695.
3. 3007.
4. 87.57, 86.95.
5. 83.75.
6. 1042.7, 5349.
7. 92.43, 89.1.
8. 3.691×10^{-10}.
9. 11.373×10^{-15}.
10. Full-load (95.6 amp.) loss 834.
11. 20.45 kw.
12. 89.1, 90.5, 89.5, 88.0, 86.1.
13. 88.8.
14. 77.2.
15. 75.7, 9.852.
16. 12,820.
17. 90.9, 93.4.
18. 521.2, 1737, 26.58, 91.56%.
19. 90.1.
20. 13.01 h.p.
21. 78.3.
22. Motor, 94.3%; generator, 94.8%.

CHAPTER XV

1. 2×10^6.
2. 5.742.
3. 35.33, 33.65.
4. 1.775.
5. 210.0, 1543.
6. 1.693, 883.5.
7. 645, 604, 6.79%.
8. 644, 562, 14.68%; 731, 685, 6.71%.
9. 643, 499, 28.85%.
10. 1031, 1016, 1.477%.
11. 0.68%, 4.39×10^6.
12. 1.207, 98.6%, 49.4%.
13. 2.414, 515, 1.212.
14. 344 conductors 90×200 mils, 2-path; or 688 conductors 90×100 mils, 4-path; windings of 2 poles in series.
15. 777.
16. 723, 875.
17. 669 r.p.m.
18. 2.82, 22.4 ohms.
19. 739 r.p.m.
20. 342.2, 336.
21. 2.96, 9.38 lbs.
22. 4503.
23. 600; 10.
24. 800; 10.
25. 533.5; 10.
26. 882, 488, 418.
27. 272, 696.
28. 864.
29. 15,000, 815, 473.

PART II

ALTERNATING CURRENT

CHAPTER I

1. 200 amperes per second.
2. 1.2×10^4 maxwells per ampere.
3. 7, 5, 6 miles per hour.
4. \$33⅓, \$18.50 per mile.
5.

Current.	Kilogausses per ampere.	Kilomaxwells per amp.
0.25	48.2	964
1	15.4	308
3	5.70	114
5	3.62	72.4

6. 28,160, 17,000.
7. 1 volt.
8. 10, 0.04.
9. 3200.
10. 34,940.
11. 482, 616, 684, 724.
12. 28.16.
13. 750, 0.05.
14. 37.5, 3750.
15. 96, 192.
16. 0.16.
17. 223.9.
18. 3686, 184.3.
19. 0.06801.
20. 0.06167, 0.07578.
21. 2130, 0.1936, 3.390.
22. 2.13, 0.616.
23. 7.95, 6.24, 4.06, 2.57.
24. 0.111 millihenry, 0.000296.
25. 66, 0.66.
26. 0.8555, 1.316 sec.
28. 628.6.
29. 7.2, 0.006.

CHAPTER II

1. 9000, 2.5×10^8; 0.1 second.
2. 36,000, 14,400.
3. 1, 1.389; 2, 5.556.
4. 5×10^6, 50,000.
5. 0.025, 0.005 second.
6. 500.
7. 0.75 farad, $675,000.
8. 20,000.
9. 0.026.
10. 0.5.
11. 90, 10.
12. 25, 6.
13. $\frac{20}{21}$.
14. 952.4, 47.6.
15. 1637 volts at 0.001 second.
898.5 volts at 0.004 second.
270.6 volts at 0.010 second.
16. 12.38.
17. 0.01815 coulomb at 0.001 second.
0.05507 coulomb at 0.004 second.
0.08647 coulomb at 0.010 second.
18. 2.545.
19. 146.

CHAPTER III

1. 60, 42.
2. 60, 300.
3. 3600, 1500.
4. 7200, 3000.
5. 2-pole, 3600, 1500; $p = 20$, 360, 150; $p = 36$, 200, $83\frac{1}{3}$.
6. 86.6, 70.7, 50.
7. $p = 12$, $f = 65$ is the nearest. Change engine speed for $f = 60$.
9. 63.66.
10. 70.71.
12. 53.05, 1.061; 1; for sine wave 1.112 : 1.
13. 72.11, 1.07 : 1.

CHAPTER IV

1. 78.02, 7.802.
2. 11.85, 75° 58′; 50; $i = 16.76 \sin(\omega t - 75° 58')$.
3. 78, 9.798, 10.
4. 0.01103 henry; 3.464, 4 ohms.
5. 0.02653, 0.01327.
6. 0.1326, 89° 56′; 100; $i = 0.1875 \sin(\omega t - 89° 56')$.
7. 8.66, 0.01443, 5.773.
8. 2309.
9. 0.02667, 0.02.
10. 0.03183.
11. 72.13, 0.0998, 61 degrees.
12. 144.5, 0.2003.
13. 80, 0.01684.
14. 36.06.
15. 36° 52′, 499.5.
16. Impressed, 22.36 (max.)
17. Impressed, 104.4 (max.)
18. Impressed. 82.5 (max.)
19. Impressed, 89.44 (max.)
20. 45.36.
21. 7.15%.
22. 130 turns.
23. 62.45.
24. 0.001579, 13.16, 78° 36′; 66.7; 6.683, 84° 15′.
25. 635.9, 852.2, 86° 21′.
28. 2.07, 20.73; 1 : 4.
29. 414.8, 2.653.
30. 17.28, 1728, 5786.
31. E.m.f. 200 volts.

CHAPTER V

1. 6013, 2088, 7024; 47.75.
2. 85.4, 85.45, 3.85%, 52%.
5. 15,400; 3905, 50° 11′; 11,660, 30° 58′.
6. 230.1, 136.3, 261.8.
7. 320.5, 1269.2.
8. 29.13, 11.18.
9. 2.29.

10. 16.44, 16.67.
11. 89.14, 75.9%.
12. 75° 9′, 56° 40′, 0°; 67° 18′, 38.6%.
13. 0.2755, 60 degrees, 50%, 100%.
14. 1140.4.
15. 98.0, 107.1; 45.45%, 22.75%.
16. 850, 18.6%.
17. 95.4.
18. 84.85, 84.80, 0.0749.
19. 90.75, 42%, 95.24%.
20. 94.09, 87.0%.
21. 1044, 44.
22. 18.03, 183.6.
23. 179.5, 26.93.
24. 10,700, 6.55%.
25. 230, 4360, 6375.
26. 1232, 82.5%, 1140.
27. 59.35, $\tan^{-1} 0.298$.
28. 139.6.
29. 34.15, at 68.4%.
30. 405.7, 49° 24′.
31. 22.45, 25° 22′, 90.3%.
32. 181.7.
33. 8.66.
34. 9.39, 37° 15′.
35. 114.5, 151.8.
36. 89.4 and 21.7, 71.8%.
37. 13.64, 21.95.
39. 24.19, 97.9%.
40. Transformer 104.4 and 14.90.
Coil 105.4 and 20.46.
41. 15.5, 16.05, 43.0, 84.2%, 100.2.
42. 1579, 70.63, 31.58.
43. 101.5, 253.8, 287.1, 91.4%.
44. 257.5.
45. 453, 90.3%.
46. 173, 151, 77.9%.
47. 322.5, 96.4%.
48. 10, 10.5; 21.15, 37° 26′; 7.51, 0.0102.
49. 45.2, 67.6; 0.6, 3.48, 28° 17′.
50. 101.2, 25.06.
51. 3.38, 61.6%.
52. 0.345, 60%.

CHAPTER VI

1. 1.94, 97%.
2. 79.0, 15.8%.
3. 5.66, 70.7%.
4. 30.47, 23° 57′ lead.
5. 223.6.
6. 147.5.
7. 200, 37.7, 9.8.
8. 20.95 sin $(\alpha - 65° 14')$
9. 309.
10. 325, 170.
11. 201, 12.8, 1130.
12. 26.6, 28.4.
13. 5.004, 40, 20,000, 19,975.
15. 146.5.
16. 38.9, 53° 15′ lead, 59.8%.
17. 97.4, 15.7.
18. 73.2.
19. 614
20. 123, 5.24.
21. 42.
22. 21, 84.
23. 200,000.
24. 6.4, 11.93, 8.15, 47.5, 110.5, 34° 30′ lead.
25. 4.995, 2, 20,000.
27. 0.01874; L = 0, 24.05 leading 66° 56′; L = 0.04, 19.47 lagging 69° 26′.

CHAPTER VII

1. 40, 10.39, 63.77.
2. 161.7, 15.5%.
3. 108, 84, 103.9, 60.
4. 72.7%, 43° 20′, 165.
5. 21.65.
6. Lag 43° 57′.
7. 500, 1, 9.95.
8. 7.14 kw., 7.14 units above.
9. 10.5, 1.125 watts.
10. 3.535, 2.5 and 0 kw.
11. 8660 kw., $107,200.
12. $18,750.
13. 55° 17′.
14. 4.77 millihenries.
15. 18.25 and 7.66 millihenries.

CHAPTER VIII

1. 42.42.
2. 176.8, 707.
3. 2309.
4. 190.5.
5. 86.6.
6. 173.2.
7. 140.4.
8. 148, 156, 165; 120° 20′, 114° 20′, 125° 20′.
9. 282.8, 1414.
10. 17.7.
13. 23.57, 16.67, 19.61; 13.1, 42.1, 40.0.
14. 46.63, 45.0, 50.78; 1.30, 1.732, 1.592.
15. 8.94 amp., 44.7%.
16. 13.8, 11.6, 10.0; 68.9, 93.1, 100.2.
17. 16.42, 9.67, 9.43; 69.6, 58.0, 48.1; 2.95, 0.91, 6.0.
18. 17.32, 10.83, 8.66, 7.85.
19. 13.6, 9.62, 11.3, 6.33.
20. 60.4, 82.7; 0.68, 1.215.
21. 344.8, 0, 216.5.
22. 7.85, 13.6; 23.55.
23. 7.76, 13.45; 41.8.
24. 12.15, 21.1; 65.4.
25. 176.8, 216.5; 200, 400; 2-phase 200, 283; 3-phase 154, 267.
26. 2120, 4245, 5510.
27. $167.88; $158.40; $167.48, $150.30.
28. 15.83, 9.14.
29. 50.99, 72.11.
30. 0.662, 1.12.
31. 17.32 kw., same.
32. 19.05, 18.03 kw.
33. 6.68, 8.85, 8.77; 4440; 79.5, 77.8, 64.2%.
34. 7.57, 2165.
35. Unity.
36. 50%.
37. 24%.
38. 53.6, 93.0.
39. 72.6, 74.0.
40. 814, 3630.
41. 250, 500; 115.5.
42. 50, 57, 73.
43. 115.5, same.

CHAPTER IX

1. 1 ohm; 1100, 2.
2. 550.
3. 0.3925, 0.09975; 8400, 12.5, 39.9.
4. 9.89, 561.
5. 4.03, 11; 0.0403, 1.1.
6. 1100; 220, 110.
7. Series 13.65, 2.73 amp., 1100, 220 volts, 3.518, 0.1407 ohm, 9.6, 1.92 volts, 1.745%; parallel 5.46, 27.3 amp., 550, 110 volts, .880, .0352 ohm, 4.8, .96 volts, 1.745%.
8. 7800, 7222, 5200, 7800.
9. 1 to 1.914; 4 to 9.
10. 10.4% decrease, 16.7%; 6.65%, 8.8%.
11. 14.1%, 17.4% decrease; 2.07% decrease.
12. 295.4, 47.8, 343.2; 137, 19.4 156.4.
13. 87.5, 5.55, 93.05.
14. 57.1,3 .37,60 .47; 123, 8.30,131 .3.
15. 81.
16. 98%, 97%.
17. 95.4%, 94.3%.
18. 0.0025; 98.2, 98.4, 98.3, 97.6%.
19. 95.6%.
20. 96.6, 96.8, 96.55, 94.2%; 91.4%.
21. 329, 17.9, 346.9.
22. 45,450; 45,450, 17,050; 45,450, 154,550; 1 : 0.545 : 1.549.
23. 45,450, 90,900; 45,450, 62,500; 45,450, 200,000; 606 : 526 : 741; 3 : 4; 1 : 2.13; 1 : 1.055 in favor of single circuit in each case.

24. 306.5, 102.3.
25. 48.8.
26. 65.5.
27. 1.128.
28. 127.
29. 46.2.
30. 75, 130; 220, 246, 246.
31. 346.4.
32. 57.73, 100.
33. 220, 5 to 1.
34. 55 turns, tap at 40.4 turns.
35. 86.6 volts, 90 degrees.
38. 110, 110, 190.5; 110, 123, 123.
39. Max. I, 3.98 at no load, 14.75 at 10 amp. load.
40. 2.993.

CHAPTER X

1. 0.2, 90°; 1.019, 11° 19′; 2.01, 5° 45′.
2. 1.113, 38° 57′; 2.107, 34° 43′; 0.917, 19° 10′; 1.907′, 24° 30′.
3. 0.3, 0; 0.853, 93.9%; 1.623, 98.2%.
4. 11,000, 13.54, 93.8%; 11,000, 11.65, 80.5%.
5. 11,590, 2104, 13.54, 36° 24′; 11,590, 2104, 11.65, 20° 15′; 5.5.
6. 41.6, 42.0.
7. 41.7, 77.7%, 2356, 214.4; 42.1, 39.5%, 2288, 207.2.
10. 227, 1259, 20.8; 228.4, 1250, 22.3.
11. 20.8, 5.6 to 1; 22.4, 6.22 to 1.
12. 80.8, 6° 51′.
13. 12.77, 1555, 355.9.
15. 5.62, 0.092; 5.8, 0.612.
16. 7.5, 305.5, 19° 23′, 100, 98.1; 7.37, 306, 6° 17′, 100, 98; 7.15, 306, 7° 10′, 100, 98.1.
17. 2.22 : 1; 2.12 : 1; 2.02 : 1.
18. 88.8, 79.8, 134.2, 200; 322.6, 299, 258.
19. 5.26%, 20.9%, 36.6%, 34.4%; 7.4%, 15.55%; 12.35%.
20. 30.85%, 32.8%, 21.13%, 12.94%; 17.2%, 2.04%; 32.08%.
21. 19.5%, 18.7%, 23.5%.

CHAPTER XI

1. 0.0866, 0.05, 0.1.
2. $2.9 + j\,1.35$, $-1.044 + j\,5.9088$, $-2.8987 - j\,2.8987$, $0.0013 - j\,1.54$.
3. $0.8944 + j\,0.4472$, $0.8944 + j\,1.7888$, $-2.1213 + j\,2.1213$, $-0.3325 + j\,4.3573$.
4. $38.53 + j\,31.213$, 49.57, 0.811.
5. 49.5.
6. 24.8, 17° 24′.
7. $35 + j\,188.5$, 191.7, 79° 28′.
8. 39.05, 50° 12′; 116.6, 30° 58′; 154.02, 35° 45′.
9. 230.2, 136.3, 261.8.
10. 0.2, 0.22, 0.297; 10, 0.75; 20, 1.333; 29.7, 0.909.
11. 373.13.
12. 34.17, 68.4%.
13. 15.5, 16.05, 43.0; 84.2%, 100.2.
14. 257.5.
15. 30.47, 23° 57′ lead.
16. 325, to 170.
17. 2056.9.
18. 2102.4.
19. 16.9; 0.438.
20. 17.1.
21. $218.85 - j\,1.0075$; abs. 218.84.
22. $218.51 - j\,0.246$, abs. 218.50.
23. $-3015 - j\,12.95$, abs. 3075.1; 1.02%.
24. $-3079.5 - j\,3.82$, abs. 3079.5; 1.35%.

CHAPTER XII

4. 5.8, 5.778.
5. 16.96%, 37.19%; 49.44%.
6. 24.9%, 12.9%.
7. 17.89%, 3.74; 45.4%, 21.8.

CHAPTER XIII

1. 4310, 3480; 4147, 2917; 2918, 1250.
2. 2037, 228.8; 2334, −269.0; 2421, −1200.
3. 37.02, 1.53.
4. 2084.
5. 458.
6. 10-ampere case impossible for this excitation; 83.4%, 94.8%.
7. 98.7%, 11.85 kw.; 98.99% lead, 29.69 kw.; 99.45% lead, 47.74 kw.
8. 10-ampere case impossible; 62.07%, 18.25 kw.; 85.14%, 42.38 kw.
9. 40, 65, 1.92, 38.73; 47.73, 192, 45.81; 45.62, 1.92, 43.7.
10. 0.3835, 0.3378, 0.2959.
11. 98.81, 99.68, 100.0%.
12. 94.2, 90.6, 93.4.
13. 99.9, 29.12.
14. 24.27, 43.58, 181.75, 245.
15. 11.72, 28.93, 45.8; 193.8, 256.
16. 27.06, 43.65, 136.2, 202.
17. 8.22, 27.5, 42.92; 90.9, 123.
18. 5926, 3138, 5926.
19. 93%, 217.2, 228.4.
20. 216.2.
22. 81, 0; 1080, 150; 379, 75; 126, 1393.
23. (a) 1034; (b) 15.6, 16.9 kw., 62.9, 37.5; 67.6, 32.84 kw.
24. 5454; 157.8, 99.76%.
26. 2897.

CHAPTER XIV

3. 55, 67.35, 38.9.
4. 91.92, 67.42, 50.56, 33.7.
5. 2829, 3266, 4000, 5656.
6. 176.8, 265.2, 353.6, 530.4.
7. 212.2, 300; 275.6, 259.8; 300, 212.2; 318.3, 150.
8. 140.8, 162.6, 115.
9. 336.8, 10.51.
15. 884, 5667.
16. 1372, 1672, 2030.
17. 194.11, 238.22, 282.34.
18. 9.24 lb., 15.6 lb.
20. 0.2706, 0.462.

CHAPTER XV

3. 0, 10, 30, 60.
4. For 12-pole, 250, 400, 600, 1000.
7. 1.694.
8. 216.7, 480; 198.8; 10.55, 5.31.
9. 66.16%.
10. 0.022, 831.1, 650.1.
11. 1588, 84° 17′; 379.4, 16° 47′; 0.1093, 42° 35′.
13. 15.7, 13.67%; 90.6%.
14. 17.3, 88.2%, 5.720 kw., 7.722 kw., 74%, 10.96%, 6424.
15. 138.5, 43.87 kw, 73%, 20.8%, 81.6%.
16. 0.0452, 0.0388 per phase.